THE ANIMAS WATERSHED PLAN

Plans for Remediation of Historical Mining Sites

In the Upper Animas River Basin

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I. INTRODUCTION

The Animas River Stakeholders Group (ARSG) is a collaborative effort involving a wide range of public and private interests including the Colorado Water Quality Control Division (WQCD) and the EPA, Region VIII. The group is committed to an interactive, open forum where all interested parties are involved in the design and implementation of watershed improvements. The mission of this group is to improve water quality and aquatic habitat throughout the Animas Watershed. The primary focus of attention is directed to reducing water quality and habitat impacts created by historical mining practices in the Upper Animas basin, near or above Silverton, Colorado. Activities include monitoring and analyzing water quality data, assessing the impact of contaminants and channel modifications on aquatic life, evaluating the feasibility of cleanup actions and formulating, implementing and assisting with remediation activities

The ARSG has no direct authority; however it developed an extensive Use Attainability Analysis used to recommend the establishment of appropriate stream use classifications and standards that are based upon partial remediation of major anthropogenic sources of metals pollution. The UAA also sets remediation objectives that will lead to attainment of those classifications and standards within a 20 year period. In addition, the group provides monitoring, characterization, and remediation technical expertise to appropriate land managers, regulatory and enforcement agencies, and private landowners. The ARSG has an established record of obtaining funds and implementing programs that establishes environmental stewardship while improving water quality and aquatic habitat.

Through education programs and participation in this collaborative stakeholder process, it is anticipated that renewed community stewardship will achieve cost effective and long-term protection of our water resources.

This Animas Watershed Plan is based upon the Animas Use Attainability Analysis (Simon et. al., 2001). Recommendations made for use classifications and numeric stream standards throughout the basin have since been adopted by the WQCC and approved by the EPA. The standards were adopted based upon detailed information provided in the UAA as to sources to remediate, associated costs, expected reductions, and the biological potentials of the receiving streams. A Table of Contents of the UAA is provided in Appendix A. A CDROM copy of the complete document (exceeding 1000 pages, not including the database) is available by contacting Bill Simon at (970) 385-4138 or email: wsimon@frontier.net.

In 2002 the WQCD adopted 29 Total Maximum Daily Load limits for streams throughout the Upper Animas watershed above Baker's Bridge, which is located 12 miles north of Durango (Figure 2). The TMDL's were developed from the existing conditions and newly adopted standard calculations provided in the Animas UAA, Chapters X and XI.

II. PROBLEM DESCRIPTION: CAUSE AND SOURCE IDENTIFICATION

This Plan has been specifically written for the Animas River and its tributaries above Baker's Bridge. A map of the area is provided as Figure 1. Major tributaries to this upper portion of the Animas include Cascade, Needle, Elk, Mineral, and Cement

Creeks. Below Baker's Bridge the Animas River flows to its confluence with the San Juan River in northern New Mexico.

The existing physical, chemical, and biological conditions related to water quality have been monitored for several years, analyzed by the ARSG, and condensed into the Animas Use Attainability Analysis (Simon, 2001). The following paragraphs are directly quoted from Chapter III, pages 2-5 of that document.

WATERSHED CHARACTERIZATION

Much of the work done by ARSG and done under the AML program has been characterizing the watershed. This includes identifying and understanding the sources of metal loading and how those loads are transported down the watershed, identifying factors that may limit aquatic life such as metal loading and habitat, and analyzing sediment data for metal concentrations pre- and post-mining. The following paragraphs briefly summarize some of the data that have been collected. Later chapters describe the results of analyses of the data. Many of the actual studies are included in the Appendices.

The shear size of the Upper Animas Basin and multitude of loading sources, whose contributions change with the seasons, has made watershed characterization a monumental task. The Basin includes three major drainages: Mineral Creek, Cement Creek, and the Animas River. It covers 146 square miles - 93,000 acres (Leib, 2000) and has over 1,500 patented mine sites. U.S. BLM has inventoried another 300 unpatented sites on its lands. (Hite, 1995) In addition, the Colorado Geological Survey inventoried sites on U.S. Forest Service land in the La Plata and Animas River drainages and found over 800 sites. The majority of these were in the Upper Animas Basin. (Lovekin et al, 1997) While all of these site contribute substantial metal loads, a large amount of loading comes from non-identifiable sources.

Water Quality Data

Some of the first investigations into water quality on the Animas River occurred in the 1960's. More water quality work and a couple of biological studies were completed in the 1970's. These reports are summarized in a report by Allen Medine (Medine, 1990). A use attainability analysis was conducted on the Upper Animas River and Cement Creek in 1984 by Western Aquatics for the Standard Metals Corp., owner at the time of the Sunnyside workings (Western Aquatics, 1985). All of these studies identified heavy metal loading as the main inhibiting factor to aquatic life.

It is difficult to compare much of chemical and biological data from these earlier investigations to studies conducted in the 1990's because the parameters measured and field and analytic techniques used were frequently different than those measured and used today. However, it does appear that there have been definite improvements in water quality and biologic health of the Animas River. Some of the same chemical parameters have improved and more fish have been found in the Basin.

From 1991 to 1993, WQCD collected substantial amounts of chemical and biological data for the 1994 rulemaking hearing discussed in Chapter I (WQCD, 1994). The information identified the main, general source areas for heavy metals. These studies have been greatly expanded upon by ARSG and the AML program throughout the nineties.

The early nineties data included a wide variety of constituents because no one know exactly what might be impair aquatic life. Samples were tested for a full suite of metals. The metals that appear in concentrations that cause concern are: cadmium (Cd), copper (Cu), lead (Pb), aluminum (Al), iron (Fe), zinc (Zn), and manganese (Mn). In addition, the Colo. Dept. of Public Health and Environment under CERCLA funding did extensive sampling for organic chemicals that might affect aquatic life. They found virtually none. (Farrell Price, 1999) Results are discussed in Chapter 9.

Four gaging stations have been set up and maintained for the past seven years in the Basin. Two stations are located at the mouths of Mineral and Cement Creeks as they flow into the Animas. The other two are located on the Animas; one just above the confluence with Cement Creek and the other below the confluences with Mineral and Cement Creeks (below Silverton). This last site is referred to as A-72. Water quality data is generally collected monthly at these sites by a variety of different entities.

High flow and low flow synoptic (meaning same day) samplings have been done on all three major drainages – eight synoptic samplings altogether. Each synoptic sampling on Mineral and Cement Creeks was run in one day. The Upper Animas River was broken into two parts, above and below the old townsite of Eureka.

These sampling events involve taking flow measurements and water quality samples at fifty to eighty different locations along each main stem, bracketing incoming tributaries. All draining adits in each sampling area were sampled the next day. These efforts, involving personal from many agencies and a number of volunteers, provide the basis for determining metal loadings from different areas.

In addition to the synoptic samplings, eight tracer experiments have been run at various locations. Tracer experiments were run over the entire length of Mineral and Cement Creeks and significant parts of the Upper Animas River during low flow. Other tracer experiments were done on particular sub-segments in the Basin.

For a tracer experiment, a consistent salt concentration is injected into a stream. Water samples are taken at intervals, perhaps a hundred yards apart, over a stream segment to be tested. By measuring the dilution of the salt concentration at each interval, the in-flow of water between intervals can be determined. If the flow of all surface water entering between sampling sites is measured, the groundwater inflow can be calculated. Water samples are also analyzed for metal concentrations. Therefore, sources of metals, including groundwater sources, can be precisely identified. (For a much greater description of the process, see Kimball et al, 1999.)

Very intense water quality sampling was done in three smaller, sub-basins in the area. Every seep, spring and draining adit that could be identified was sampled and flow measured. By comparing all of these loads to the load found at the mouth of the drainage, the relative contributions of natural versus human-induced metal loading could be estimated (Wright, 1997).

Different companies and agencies also did substantial sampling around potential remediation sites. Sites that have been or are undergoing remediation are listed in Table 3-1 below. Overall, a total of about 4,000 to 5,000 water quality samples have been taken.

Locating and Sampling Waste Rock and Tailings Piles

As part of the AML Initiative, surveys locating sites of past mining activity on public lands have been completed. Many sites lie on a mixture of public and private land.

A number of material samples were collected from each of approximately 250 waste rock piles (dumps) and tailings piles in the basin. These samples were tested for acid generation potential and heavy metal concentrations.

Sediments

Sediment samples were collected from the river bottom along the entire 110 mile length of the Animas River to help determine the sources of metal loads. (Church et al., 1997) Older sediments were also collected at strategic locations to analyze the changes in metal concentrations from pre- to post-mining periods. (Church et al., 2000).

Biological Data

Macroinvertebrate data has been collected twice at approximately fifty sites throughout the length of the river. The initial impact of improvements in water quality will most likely show up in macroinvertebrate counts downstream.

The Colorado Division of Wildlife (DOW) has done several electro-shocking fish studies in the Animas River both around Durango and in the Basin. Surveys have shown improvement in fisheries between 1992 and 1998.

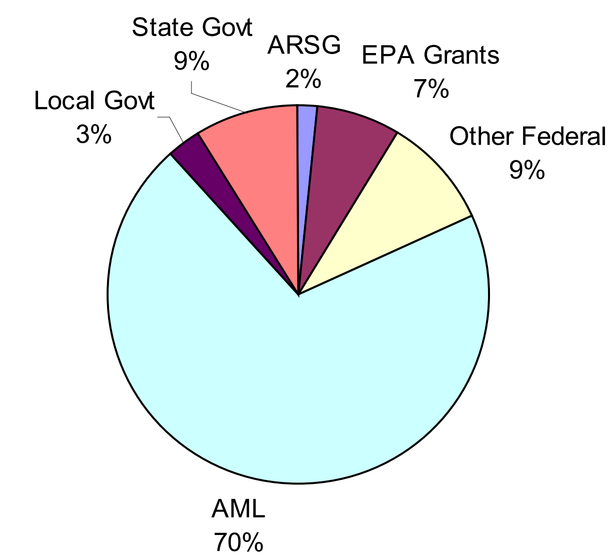
Other biological studies have examined factors that might limit aquatic life including: toxicity of metal concentrations, the possible synergistic effects of copper and zinc togther, toxicity of water in the pore space in the substrate, the effect of smothering of the substrate with iron and aluminum compounds, and the amount of spawning habitat.

Geology and Initial Remediation Plans

The Colorado Division of Minerals and Geology and U.S. Geological Survey have mapped and described many of the geologic features in the Basin that can be sources of loading and can buffer the acidity. The Division also devised initial remediation plans *for most of the inactive and abandoned mine sites throughout the Basin. (Herron et al, 1997, 1998, 1999)*

Overall a prodigious amount of effort have gone into characterizing the Upper Basin. So far over $7.2 million has been spent. Some work is still in progress. Figure 3-1 shows funding sources for characterization and coordination in the Basin over the past ten years. Yet with all of these resources committed to characterization, even more resources have gone into actual remediation.

Figure 3-1 - Funding for Characterization and Coordination



Source: Rob Robinson, U.S. BLM, Denver, CO, unpublished spreadsheet on expenditures in the Upper Animas Basin plus personal communication with other stakeholders.

III. REMEDIATION METHODS, RANKING, AND PRIORITIZATION
(COPIED AND MODIFIED FROM CHAPTER X OF THE ANIMAS UAA)

This section discusses what can be done to eliminate or reduce the mine-related loading sources. It also describes a prioritization process that ARSG has conducted for targeting sources in order to get the "biggest bang for the buck" in metal reduction.

Remediation can be classified into two broad categories: preventative measures and treatment. Preventive measures are designed to minimize the chemical, physical and biological processes that cause metal loading and increase acidity. The main method, called hydrologic modification, is to try to keep water, oxygen, and acid generating material separate. Other remediation efforts involve treatment of water that is already acidic and/or carries high concentrations of metals. Treatment can be passive where the treatment processes need only periodic maintenance or active where the processes need frequent maintenance and supervision.

FIGURE 1

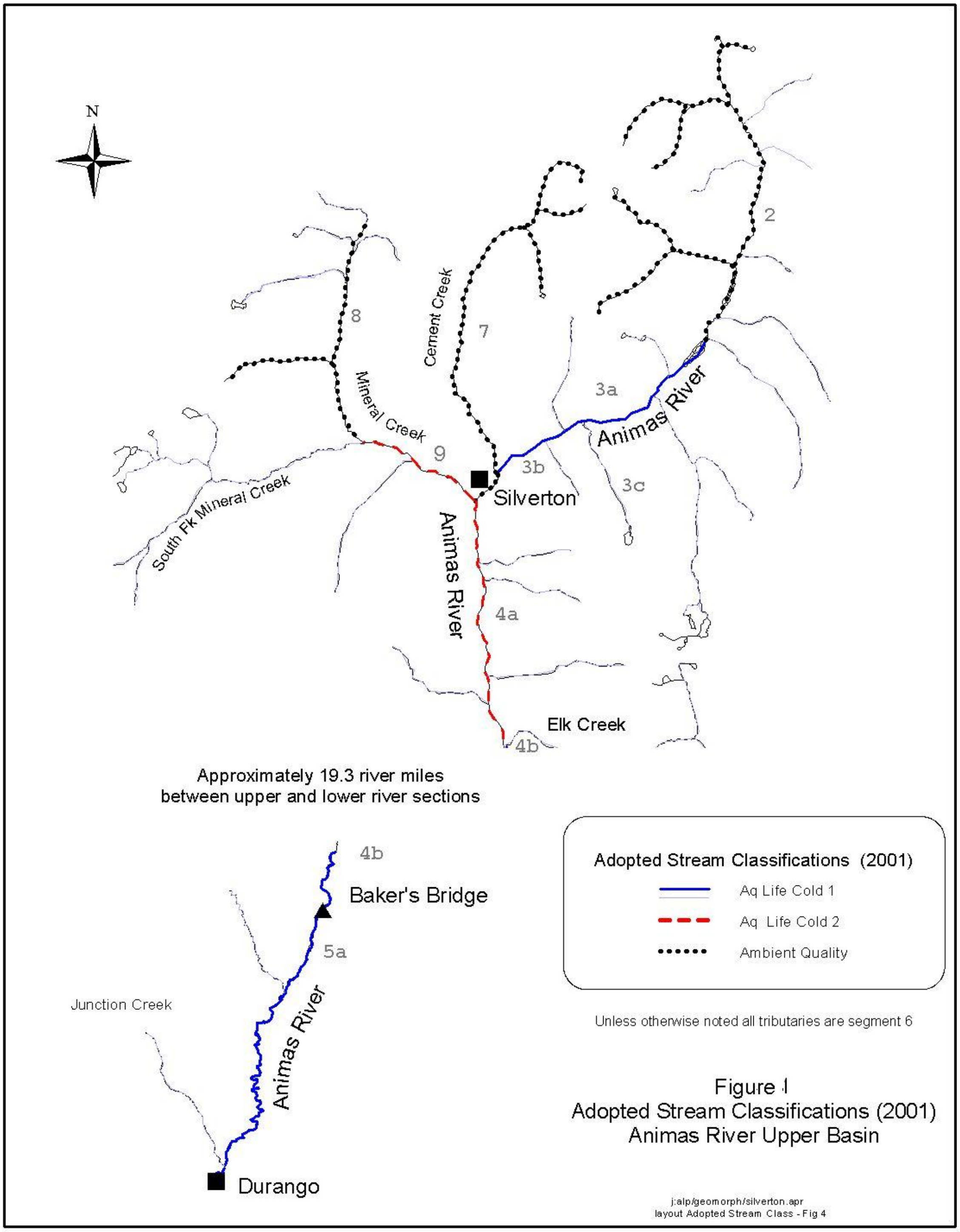

N
2
8
7
Cement Creek
Mineral Creek
9
3a
Animas River
3b
Silverton
3c
South Fk Mineral Creek
Animas River
4a
Elk Creek
4b
Approximately 19.3 river miles
between upper and lower river sections
4b
Baker's Bridge
5a
Junction Creek
Animas River
Durango
Adopted Stream Classifications (2001)
Aq Life Cold 1
Aq Life Cold 2
Ambient Quality
Unless otherwise noted all tributaries are segment 6
Figure I
Adopted Stream Classifications (2001)
Animas River Upper Basin
j:alp/geomorph/silverton.apr
layout Adopted Stream Class - Fig 4

Figure 2

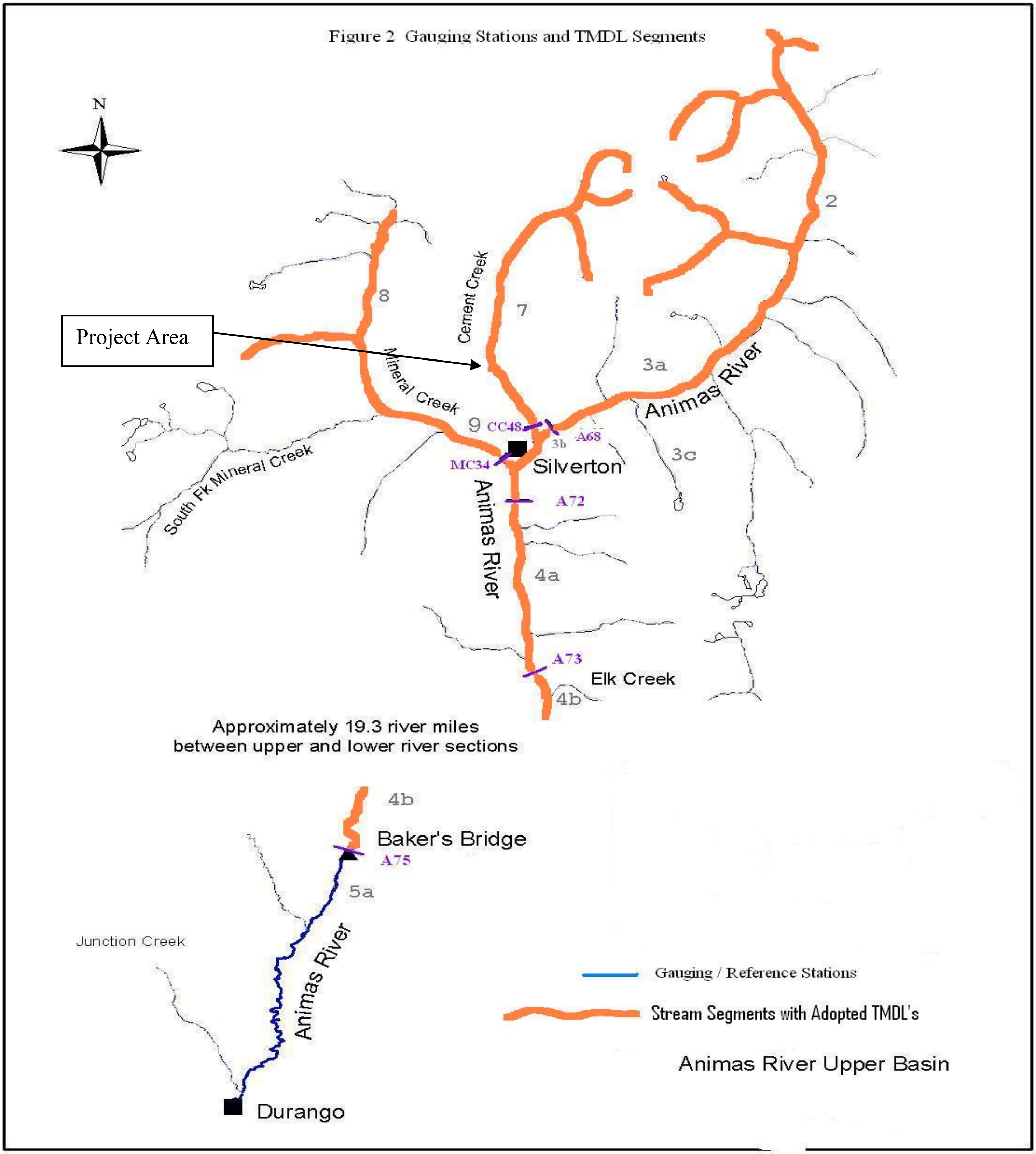


Figure 2 Gauging Stations and TMDL Segments
N
Project Area
Cement Creek
7
8
2
3a
Animas River
Mineral Creek
9
CC48
3b
A68
Silverton
MC34
3c
South Fk Mineral Creek
Animas River
A72
4a
A73
Elk Creek
4b
Approximately 19.3 river miles
between upper and lower river sections
4b
Baker's Bridge
A75
5a
Junction Creek
Animas River
Durango
Gauging / Reference Stations
Stream Segments with Adopted TMDL's
Animas River Upper Basin

Introduction to Remediation Methods

The Colorado Division of Minerals and Geology has prepared four reclamation feasibility reports for the Upper Animas River Basin (Appendices 10A, B, C, and D of the UAA). Remediation of historical mine sites in the upper Animas will utilize the most feasible methods on a site-by-site basis according to waste characterization, site access, and disposal restrictions.

<u>Surface Hydrologic Controls</u>

Most hydrologic controls are preventative measures in that they inhibit or prevent the process of acid formation and/or heavy metal dissolution. If it is possible to prevent water from entering a mine, or coming into contact with sulfide ores or wastes, this can be the best, most cost effective approach. Here are excerpts on surface hydrologic controls from Herron *et al* (1999, p. 27):

> <u>Diversion ditches</u> are effective where run-on water is degraded by flowing over or through mine waste, or into mine working. Diversion ditches can also be used to intercept shallow groundwater that may enter mine waste. In some cases, mine drainage can be improved by flowing through waste rock. Mine drainage must be sampled above and below a waste rock pile to determine whether the waste rock is actually degrading the water quality.
>
> <u>Mine waste removal and consolidation</u> is effective where there are several small mining waste piles in an area, or where there is a large pile in direct contact with flowing water. The method is simply to move reactive material away from water sources.
>
> <u>Stream sealing or diversion</u> involves moving the water sources away from reactive materials. Or sealing/lining streams to prevent surface inflows into shallow mine workings through stopes, shafts, or fracture systems. It may include lining or grouting/sealing the streambed or bedrock.
>
> <u>Revegetation</u> is often used in combination with other hydrologic controls above. Revegetation by itself can be a very effective method of reducing heavy metal concentrations, particularly where much of the metals come from erosion of mining waste into a stream. Revegetation also reduces the amount of water that infiltrates a waste pile, thereby reducing leachate production. The roots of growing plants also have been shown to produce carbonates through respiration.

In addition and often in conjunction to these methods, mine waste piles may be capped and amended with neutralizing agents (*e.g.* limestone, lime, fly ash). A cap can only reduce surface moisture infiltration. Throughflow and groundwater upwelling can also occur and the impervious cap could result in increased humidity to the mine waste resulting in increased salt formation and eventual loading to nearby streams. The effectiveness of the amendment depends upon many site-specific factors.

Subsurface Hydrologic Controls

Subsurface hydrologic controls are in-mine measures that inhibit or prevent the process of acid formation and/or heavy metal dissolution into the ground or surface water system. If it is possible to prevent water from entering a mine, or from coming into contact with sulfide ores or wastes, or mixing with contaminated water plumes in the workings, this can be the best, most cost effective remediation approach, because it helps prevent the problem, rather than treating its symptoms in perpetuity. The success of most hydrologic controls depends on understanding the sources and hydrologic pathways of waters that enter the mine workings and discharge from the mine workings through groundwater and surface pathways to determine how best to segregate or seal off particular water sources in the workings. Here is more discussion from Herron *et al* (1999, p. 30).

> In-mine diversions are effective where clean groundwater inflows are degraded by flowing through drifts (on veins) and stopes in the mine workings. The concept is to intercept the inflows before they come in contact with metals loading source areas in the mine, thus circumventing metals contaminant production in the mine workings/ore body. The “clean” inflows are then diverted to the surface stream through a collection and piping system. Though in many cases it may not be possible to intercept all inflows before they become contaminated through contact with the ore body, it is often possible to segregate and divert much of the groundwater inflow before it mixes with the contaminated plume. This can greatly reduce the overall quantity of polluted outflow. By significantly reducing mine discharge, it may then become cost-effective and feasible to treat the segregated contaminate plume through passive or semi-passive techniques; the effluent flow is minimized, and concentration may be adjusted for optimum system performance through dilution with part of the diverted clean flows.
>
> Grout sealing a fracture inflow zone at a discrete location can prevent groundwater from entering the workings, using proven, existing “ring-grouting” methods and technology. The concept for this technique is to seal water inflows through a grouting program, similar to those used to seal dam foundations, and control water inflows to active underground mining operations. Chemical or cement grout is pumped under pressure into an array of holes drilled radially out from the drift in and along the plane of the water bearing fracture or fracture zones. The grout enters and seals the fracture pathways that communicate with the mine opening. If engineered and executed correctly, the water is prevented from entering the excavation, and is forced far enough back into the rock away from the mine workings so that it resumes its pre-mining course, flowing around the grout “curtain”. Depending on conditions and the layout of the workings, care must be taken to ensure the inflows are not simply diverted to a point where they

enter another part of the ore body. Ideally, the grout curtain would be in position where no other lower or upper levels are nearby, and where numerous small fractures or one discrete structure is draining groundwater into the workings along a relatively short section of drift.

Bulkhead seals are another type of preventive or "source control" measure. The concept is that geochemical and flow equilibrium will be reached in the groundwater, whereupon anoxic conditions in the flooded workings will prevent or reduce dissolution and transport of heavy metals. Bulkhead seals are designed to prevent discharge to surface water through the adit opening by blocking the flow with an engineered hydrologic plug, flooding the mine. For most inactive mines, bulkhead seals are expensive and require considerable geologic and engineering investigation and characterization. Sites that have simple geology, sound rock, and limited subsurface workings may be amenable to this approach.

Sometimes water inflow into mines can be reduced from remedial measures implemented outside of the mine workings. For example, grouting or sealing fracture areas may be done from the surface. A mine near Eagle, Colorado, installed a well near a fracture zone to lower the water table. But all these hydrologic controls may not be enough or may be almost impossible to implement depending on specific characteristics of a site. Discharge from adits may need to be treated. There are a wide range of options, all of which have positive aspects and drawbacks. Generally, treatment involves raising pH levels if they are low and precipitating metals.

Passive Treatment Techniques

Passive treatments have received a lot of attention from mine-drainage remediation specialists because of relatively low costs, low maintenance, and effectiveness. Here is a summary of passive treatment techniques from Herron *et al* (1999, p. 28):

Anoxic limestone drains are the simplest method of introducing alkalinity into mine discharges. Anoxic limestone drains (ALD) are constructed by placing coarse limestone (3/4" – 3") inside an adit or in a fully sealed trench outside a discharging mine. In order for an ALD to function properly, the mine discharge must be devoid of oxygen. In the absence of oxygen, limestone will not become coated by iron and other metal hydroxides, which can shorten the useful life of limestone. In addition, the mine drainage should be relatively low in dissolved aluminum. Aluminum has been shown to precipitate in ALD's, causing plugging. It is theorized that very coarse limestone (4"-6") should provide large enough pore spaces to minimize or prevent clogging by aluminum. The disadvantage of using larger limestone is the reduced surface area to react with the mine drainage. After the mine drainage exits the ALD, aeration causes precipitation of metals. The increase in pH due to ALD's is site specific, but generally does not exceed two standard units.

Settling ponds are often overlooked as an effective treatment method. Settling ponds are particularly effective for treating near neutral mine drainages high in total suspended solids (TSS). Aeration of a near neutral pH mine drainage by means of a series of drops, followed by a settling pond can effectively remove iron and other metals that co-precipitate with iron. Settling ponds should be designed for a 24-hour or greater retention time wherever possible.

Sulfate reducing wetlands are often called bioreactors. These systems treat water through bacterial reduction of heavy metals. Sulfate reducing bacteria (SRB) utilize the oxygen in sulfates for respiration, producing sulfides. The sulfides then combine with heavy metals to form relatively insoluble metal sulfides. The bacteria derive their energy from a carbon source such as cow manure or mushroom compost. There are many other substrates that are an acceptable source of carbon, but most have a low hydraulic conductivity that can result in short circuiting of the system by formation of preferential flow paths. Sulfate reducing bacteria cannot survive in a drainage with pH below 4.5. Highly acidic drainages will require a pH increase before the effluent enters the bioreactor.

Sulfate reducing wetlands should generally not be constructed near population centers. These systems commonly produce excess hydrogen sulfide, which can cause undesirable odors up to three miles from the system. When initially started, organics in the substrate discolor the treated water for several months, making water quality appear, to the layman, to be worse than that entering the system.

Aqueous lime injection is a passive method to introduce neutralizing agents into mine drainage. This system requires a clean water source. Clean water is passed through a pond containing neutralizing agent, then the high pH effluent is mixed with the mine drainage before it enters a settling pond. This system can be cost effective if the alkaline wastes such as kiln dusts or fly ash are available. Although still in the experimental phase, the method holds promise for some mine sites. Neutralizing materials may also be injected into stopes and drifts.

Limestone water jets are an aerobic method of accelerating the dissolving of limestone. In situations where mine drainage flows down a steep slope, the discharge can be piped, and the resultant head can produce a high-pressure water jet. The high-pressure jet can be either sprayed onto loose crushed limestone, or passed upward through a vessel containing limestone. In both situations, the limestone does not become coated because of abrasion by the water jet, and agitation of the surrounding clasts. The system using a vessel can result in higher alkalinity in the effluent due to greater abrasion. Both system types are in the experimental phase.

Oxidation wetlands are what most people think of as “wetlands”. They differ from sulfate reducing systems in that metals are precipitated through oxidation, and aquatic plants must be established. This treatment method is applicable where the pH of mine drainage is approximately 6.5 or higher, and where metals concentrations in the drainage are primarily a problem during summer months. Aeration is an important part of the system. The plant materials provide aeration and, when they die, provide adsorption surfaces, along with sites for algal growth.

<u>Aeration</u> is best used where the mine drainage pH is about 6.5 or above. Aeration promotes metal precipitation through oxidation processes. Aeration can be accomplished by mechanical means, or simply by channeling the drainage over rough slopes. Mechanical methods require some source of power, which may be generated through wind, solar cells, or hydropower. Aeration methods normally include a settling pond below the aeration component.

<u>Mechanical injection of neutralizing agents</u> involves a powered mechanical feeder/dosing system for dispensing neutralizing agents. This type of system requires frequent maintenance, may produce significant quantities of metal sludge, and should be considered "semi-passive." Power for the feeder can come from wind, solar, or hydropower. At the Pennsylvania Mine in Summit County, a turbine running in the adit discharge stream demonstrated that hydropower is practical in some situations. Mechanical systems are generally considered only where there are no options for truly passive alternatives. Any high pH material can be used in this type of system. Because of cost effectiveness and sludge characteristics, the most common neutralizing agent is finely ground limestone.

<u>Dilution</u> is often overlooked as a treatment method. It can be a cost effective method of treatment, because the neutralizing agent is simply uncontaminated water. Clean water is mixed with the mine drainage in a settling pond, and the resultant pH increases initiates precipitation of metals. A drawback to this method is that the percentage of metals precipitated is significantly less than other methods. Metal removal is site specific, but generally less than 50%. This method is most effective in removing iron, aluminum, copper, cadmium, and lead, but has only slight effectiveness for zinc and manganese.

<u>Electro-kinetics</u> is a newer semi-passive method to remove metals from mine drainage. There are several forms of this treatment currently being developed. The electro-kinetic method discussed in this report uses a low-maintenance, self-regulating resin to remove metals from mine discharge. Different metals can be separated by using ion specific resins. Electricity is used to strip metals from the resins, producing sludge, and allowing re-use of the resin.

<u>Land application</u> is a method designed to use natural metals attenuation processes in soil and subsoil to remove metals. Plant uptake, evaporation and transpiration, and soil exchange capacity act to tie up and remove metals. This method is most effective where mine discharge can be spread over a large area

> to infiltrate into relatively thick soils or unconsolidated deposits. Drainage should be neutral or near neutral to avoid plant toxicity. This alternative is also effective for discharges with high iron and/or aluminum, where pH is approximately 4.5 or above.

In addition to these passive and semi-passive techniques, there are active systems that operate in much the same manner but have more mechanical mechanisms and need more maintenance.

IV. REMEDIATION IN THE UPPER ANIMAS BASIN

Of the 35+ projects completed or in progress in the Upper Animas Basin as listed in Appendix B, 21 are surface hydrologic control projects. There are also four subsurface hydrologic control projects, all using bulkhead seals. Five different passive techniques are in use or have been used in the Upper Animas Basin including injection of a neutralizing agent, anoxic drains, a wetland, a bioreactor, and settling ponds. At some sites a combination of techniques have been used. Sunnyside Gold's treatment plant at the American Tunnel is the only active treatment facility. It consists of mechanical injection of a neutralizing agent followed by a series of settling ponds. The plant has recently been purchased by Silver Wing Co. Currently Silver Wing Co. is treating what little discharge remains from the American Tunnel and discharge from the Gold King Mine.

Challenges in Doing Remediation

Remediation is site specific and most of the sites in the Upper Animas Basin offer substantial challenges. Many sites lie on steep slopes at elevations 10,000 to 13,000 feet above sea level where it can snow any day of the year, and snow depths can reach 12 to 15 feet in winter. The construction season may last only three to four months. Avalanches are a constant hazard for at least half of the year and some sites lie directly in avalanche paths. Some sites have no vehicle access so that helicopters may be needed to transport equipment. Areas around the sites are fragile mountain tundra where heavy equipment can do substantial damage. Few sites have electric power needed for some types of treatment.

Hydrologic controls are the preferred method of remediation because they are frequently less expensive and need less maintenance than treatment. Drainage diversions around mine waste piles can be a good, inexpensive partial remediation method, yet it is difficult to totally isolate piles from water. Removal of mine waste piles can be a very effective remediation measure, but where does one put the material? In the Upper Animas Basin, some piles have been scooped up, consolidated, and then capped with clay or soil to reduce water infiltration. However, there are few large, flat areas in San Juan County that could be used as repositories for significant amounts of material. Trucking the wastes outside the region to a landfill would be prohibitively expensive. Another alternative is to mill the mine wastes to remove the offending metals. This alternative is currently being explored.

Many mine waste piles occur on steep slopes. As material was dumped from a portal, the piles themselves became conical with steep sides and small flat tops. Their shape makes them difficult to cap or amend with neutralizing agents.

Sub-surface hydrologic controls can be very effective, if the underground mine workings are accessible. Most mines in the Upper Animas Basin have not seen any activity in eighty to ninety years, and if entry is still possible, it is very dangerous. There may be no oxygen and the roof may collapse. Yet there are a few sites where sub-surface controls, including grouting or sealing areas above the mine from the surface may be possible, and they are being investigated.

Passive treatment must be tailored to a site and to the specific metals needing removal. Some treatment techniques can be ruled out for all but a handful of sites. Only a few sites have relatively large flat areas needed for treatment using settling ponds or wetlands, and these types of treatment lose their effectiveness when temperatures drop well below freezing during much of the year. Techniques such as anoxic drains need less space, but they need more maintenance to prevent them from clogging and are better suited for discharges with low iron and aluminum content. Metals such as zinc and manganese are more difficult to remove because pH must be raised to a high level to make them precipitate. The pH must reach about 11 to get manganese to drop out. Each site needs to be thoroughly characterized and evaluated to determine the feasibility of metal and acid removal.

Remediation Ranking and Prioritization

The Colorado Division of Mineral and Geology, with direction from ARSG, has taken a first cut at estimating the feasibility of reclamation for 140 sites (some of which have multiple features) in the Upper Animas Basin. Their four reports – one for Mineral Creek, Cement Creek, Upper Animas above Eureka, and Upper Animas below Eureka (Appendices 10A, B, C, and D of the UAA) - describe sites, diagram sites, list results of water quality and leachate data (from mine waste piles), and recommend remediation techniques. The reports are quite extensive yet most sites will require more specific process and design engineering before construction begins.

In conjunction with and addition to these reports, the ARSG Prioritization committee characterized and ranked 159 mine waste sites (waste rock piles and mill tailings) and 174 draining adits relative to one another. While ranking of sites was based upon analytical data determined through sampling, testing and monitoring, the sites were prioritized by combining ranking information with more subjective attributes. Various weights were placed on different attributes of a site depending on which attribute was thought to be relatively more important than another. This enabled the group to focus remediation towards achievement of specific goals based upon available technology, funding, and property owner cooperation. Spreadsheets containing this information were the basis for developing the remediation scenarios and calculating potential reductions. While ranking was completed during 2002, prioritization was intended to be a dynamic process to be revisited prior to each working season.

Mine Waste Piles

Mine waste piles were characterized relative to their potential impact on the environment. Certain attributes of each site are listed on the rank and prioritization spreadsheets (UAA Appendix 10F). Potential for contribution of metals and acidity to nearby streams was determined by leachate tests. Ten to twenty samples were taken from various locations of the upper six inches of surface on each mine dump or tailings pile. The samples were mixed to form a composite sample. The composite sample, 150 ml., was mixed vigorously with 300 ml. de-ionized water (2:1 ratio). After allowing clay particles to settle, part of the sample was tested for total acidity, pH, and conductance. The remainder was acidified to determine metal content. (See Herron *et al*., 1999, for more details on the process.) Some data also exists for 20:1 EPA method 1312 Leach test and Modified 1312 leach tests for several sites. This data was not included in the ranking process because it cannot be compared to the 2:1 leach test. In addition, USGS has done some leach testing using yet another sampling and analysis method.

Mine wastes were ranked by metal contributing potential for zinc, copper, cadmium, lead, manganese, aluminum, and iron and pH as determined by the 2:1 leach test. For example, the waste with greatest zinc leachate concentration is ranked number one for zinc. The same site may be ranked number five for lead if it has the fifth highest amount of lead leachate concentration, and so forth. In addition, weighting factors have been assigned for the metals analyzed. Aluminum and iron are considered limiting factors but the sources of these metals are overwhelmingly associated with natural features and processes (See Figures 8.18 – 8.21). In addition, they will automatically be reduced by any treatment method. Reductions may not even be beneficial since their presence downstream may be desirable for scavenging Zn, Cd, and Cu from solution by sorbtion to their precipitates. Aluminum and iron are given a weighting factor of one.

Manganese and lead are both given a weighting factor of two because they generally have a moderate potential as limiting factors, while their sources are more specifically identified with mine features than those of iron and aluminum. Lead falls from solution readily in the Animas watershed and will probably not be a limiting factor if treatment for other metals progresses. A handfull of sites appear to be high contributors of manganese.

Copper, cadmium, and zinc have high potential as limiting factors throughout the basin and tend to be highly correlated to mine and/or mill features. They come from a multitude of sites. These are given the highest weight factor of three.

The other weighted factor, pH, is a strong limiting factor in Mineral and Cement Creeks, but is not as significant in the Upper Animas. Some treatment methods may result in increased pH but much of the low pH is thought to be the product of natural geological processes. It is given a weighting factor of two.

To complete ranking, each of the seven metals plus pH were multiplied by their respective weighting factors then added together for each mine waste site. The resulting sum is a measure of the severity of total loading potential. Sites were then ranked for remediation by the weighted sum; the lowest number is given the highest priority. The prioritization was done for each of the three sub-basins and for all the sub-basins lumped together (Combined Rankings). That way remediation can be targeted for specific segments, depending upon in which sub-basin they lie, or by their collective impact on the Animas below Silverton.

In addition to the leach test results, many other characteristics are listed on the spreadsheets for the dumps. These are also important considerations in prioritizing sites for remediation, but have not been included as part of a mathematical sum. These include:

- site names and locations,
- the size of planer surface areas of dumps,
- volume of material where estimated by DMG,
- distance to ephemeral streams,
- distance to perennial streams,
- biological potential of nearby streams (*i.e.* potential presence of aquatic life),
- orientation (direction) of slope (indicates when snow may melt off),
- whether or not a vegetative kill zone exists below,
- relative steepness of the site,
- ease of access,
- whether or not acid mine drainage runs over or through the dump,
- potential remediation that might be applied,
- rough estimate of cost of remediation.

Some of these characteristics require additional explanation. The planer surface areas of dumps were estimated from 1998 USGS Orthophotographic Quadrangle Maps. They are considered to be overestimates because surface disturbances related to roads and portal cut banks often could not be visually distinguished from the wastes. Generally, the entire disturbed area was distinguishable and therefore measured. On the other hand, sites smaller than 80 to 100 square meters were not included because of resolution difficulties. Although there are many small prospects that fit this category, prospects seldom contain high mineral content (otherwise they would have been more extensively mined). The assumption is that the overestimate of the larger waste sites is countered by not estimating the prospect sites. Distances to ephemeral and perennial streams were also estimated using the Orthophotographic Quadrangle Maps.

Several characteristics are given a relative rating. Biological potential (of immediate receiving stream) is divided into three categories; low, medium, and high. Likewise, steepness is rated, flat, moderate, or steep. Access is rated 1 through 4, with 1 being easy and four being very difficult.

Potential remediation techniques are divided into five categories: capping, amending with neutralizing agents, removal and cleanup, hydrological controls (such as drainage ditches), and consolidation of dumps. The ARSG Prioritization Committee, which is made up of five professionals with extensive experience in implementing mining remediation, estimated typical rates of metal removal for each technique: capping – 25%, amendment – 10%, removal – 90%, hydrologic controls – 20%, and consolidation –10%. These percentages are considered additive if more than one technique is applied to a site. The reduction rates are also considered an average rate for the method over time. Some sites may provide better results; others worse. The spreadsheets show which techniques might be best applied to particular sites.

Several sites are currently listed as "no action". After careful evaluation by the Prioritization Committee, these sites were considered having a low potential of contributing metal loads to receiving streams. There are also numerous sites that were identified through Orthophotographic Quadrangle Maps as disturbed areas and have been included on the spreadsheets. Leach test samples were not collected from these sites because best professional judgement determined that metal and pH contributions would be insignificant to receiving streams.

Estimated costs for remediation are based on best professional judgement and are site specific. Administration and contingency costs are not included for individual sites but are added to the overall costs of the remediation scenarios described in the next chapter. Disposal costs of any removed material has not been included. Four cost ranges have been applied: under \$20,000, \$20,000 to \$100,000, \$100,000 to \$500,000, and greater than \$500,000. The specific remediation estimates for particular sites are shown on the spreadsheets.

Draining Adits

Adits have been characterized in method similar to dumps. The results are listed on rank and prioritization spreadsheets for each sub-basin and the complete Basin in Appendix 10F of the UAA. An attempt was made to sample all draining adits during both high and low flow time periods. Flow measurements were taken at the same time as samples. Sampling was coordinated by the Division of Minerals and Geology and ARSG (See Appendices 10A, B, C, and D - UAA). Due to the large number of adits, over 170 (some being quite remote and/or not initially located), a few adits were missed or sampled only at high or low flow periods. High flow samples were also not possible at all sites because of inaccessibility due to deep snow. Some adits had no or unmeasurable flows at low flow. ARSG is continuing to fill in the missing data.

Water samples were collected from adits in the Mineral Creek drainage in 1995-1996, in the Cement Creek drainage in 1996-1997, in the Upper Animas drainage above Eureka in 1997-1998, and in the Upper Animas below Eureka in 1998-1999. All adits were sampled the same day in each sub-basin. High flow samples were taken in late June or July. Low flow samples were taken in September or October. Additional water quality samples were taken at a number of sites by other agencies and companies participating in ARSG. Wherever multiple high flow data exist for a particular site, the data have been averaged. Multiple low flow data were also averaged. All samples were taken at the portal entrances.

Adits were ranked in the same fashion as mine waste, using seven metals, pH and the same weighting factors for each metal. Interestingly, when this ranking was compared to a ranking where the weighting factors were removed, the top twenty five adits in the whole Upper Animas Basin remained the same and order of those twenty five changed little. The weighting factors made little difference in the overall results.

Adits are also be ranked on the spreadsheets for high flow, low flow, and the combination of high and low flows in terms of metal loading and pH. It depends on what are the analytical purposes and goals of remediation efforts.

As with mine waste, other characteristics that may be important to prioritize adits for remediation are included on the spreadsheets such as:

- site names and locations,
- flow rates during high flow and low flow,
- dates of sampling if only one sample was taken during high or low flow,
- proximity of receiving streams,

- biological potential of nearby streams (*i.e.* potential presence of aquatic life),
- orientation (direction) of slope (indicates when snow may melt off),
- whether or not a vegetative kill zone exists below,
- whether or not acid mine drainage impacts dumps below the adit,
- ease of access,
- potential remediation that might be applied,
- potential effectiveness of remediation,
- rough estimate of cost of remediation.

The proximity of receiving stream is rated relatively: instream, near, medium, or far. Biological potential of the receiving stream is rated high, medium or low. Ease of access has a relative scale of 1-4 with 1 meaning easy access.

As with mine waste, the potential remediation technique for each site was based on professional judgement of the ARSG Prioritization Committee. The techniques are categorized as bulkhead seals, source controls, passive treatment and active treatment. Hydrologic controls like bulkhead seals and source controls are more desirable because there is minimal operating and maintenance costs. Source controls are means of inhibiting water from leaching metals from underground workings, either by preventing water from entering mines (*e.g.* re-routing surface waters, pressure grouting inflows) or by collecting in-flowing water before it reaches mineralized surfaces and transporting the water back to surface in an inert conveyance.

Where conditions are perfect, such as in deeply situated mine workings where water is entering far from the surface and when the rock has only minimal, small fractures, complete reduction of loading to streams might be expected using bulkhead seals. But this is an unusual situation since many adits are shallow in depth, and the surrounding rock is often highly fractured, naturally or from mining activities. Then water will find alternative pathways around the bulkhead seal.

Finding and gathering in-flowing water can be difficult and expensive. First the in-flow must be located by geophysical methods, tracer dye injections, or visual examination from the surface and within the mine. Seldom can all in-flowing water be accounted for, particularly if the underground workings include abandoned stopes and raises. As result of these difficulties, ARSG has determined that on the average, 50% reductions for these two methods would be optimistic for the typical mines and conditions presently known in the Upper Animas Basin.

The other two remediation categories are passive and active treatment. Passive treatment generally requires continued long-term maintenance and, on average, will be less effective than hydrological controls. There is a wide range of passive treatment methods available and often two or more methods can be built into the treatment of a single mine drainage. Some treatment methods (*e.g.* settling ponds) may only remove a small percentage of a single metal whereas a complex system may remove varying amounts of several metals. Given the high elevation, severe winters, high precipitation, steep slopes, and need for continued maintenance and medium renewal, it is estimated that passive treatment systems may average 30% reductions over an extended (20 year) period.

There are several methods of active treatment available. All require large initial capital outlays and annual expenditures for operation and maintenance in perpetuity. This category is consider the least desirable approach, although potentially the most effective at reducing metal loading. Active treatment plants are generally designed for reduction of specific metals. As such, they can be very effective for the metal of concern. But it is to be expected that there will be lower percentage reductions for other metals. An 85% average reduction of all metals is anticipated using active treatment methods.

In some cases, one remediation method might be tried, such as source controls, but more metals may need to be removed. After the source controls are implemented, passive treatment may be needed. The potential for this additional treatment is noted under Phase 2 of the treatment methods on the spreadsheets. Phase 1 may not be successful or only minimally. Therefore Phase II costs are a summation of the two phases. Several sites are currently listed as "no action". After careful evaluation by the Prioritization Committee these sites were considered having a low potential of contributing metal loads to receiving streams.

As with the mine waste characterization, estimated costs for remediation are based on best professional judgment and are site specific. Administration and contingency costs are not included for individual sites but are added to the overall costs of the remediation scenarios described in the next chapter. Four cost ranges have been applied: under \$20,000, \$20,000 to \$100,000, \$100,000 to \$500,000, and greater than \$500,000. Some sites were difficult to fully assess and available remediation methods did not appear to be practical to apply, particularly without further investigation. For these sites, costs reflect the next steps for further evaluation but do not include estimated percentage reductions since the most appropriate remediation method is not known at this time. The specific estimates for all sites are shown on the spreadsheets.

The rank and prioritization spreadsheets were designed to focus remediation on locations where the largest benefits could be realized for the effort and resources expended. They were not developed specifically for the UAA and are expected to change as more information becomes available. However, they are very useful for setting up different scenarios describing what metal reductions may be possible and at what cost, if a certain number of sites were remediated. Those scenarios are described in the next chapter.

Loading from the Largest Adit and Mine Waste Sources

The adits have been ranked, using the weighting factors discussed in Section II, on the basis of both high and low flow loading of seven metals plus pH. Most high flow samples were obtained in June or July, while low flow loads were obtained in September or October. These figures may overestimate low-flow loading since early fall stream flows had not yet dropped to levels seen in winter months. Loads from the Kohler, Bandora, North Star, and Evelyn mines were sampled frequently.

Selection of sites to be included for possible remediation is based upon the combined rankings of all sites within the Upper Basin (Appendix 10E - UAA). Many sites were previously categorized as "no action" because of their low total contributions and remoteness and/or low concentrations. The loading from the top ranking 33 adits, including a few large loaders lacking either a high or a low flow sampling datum, are shown in Table 11.1. These are current loading figures and do not include any potential reductions. Eighty nine percent of the loading from all adits comes from these top 33 sites.

Mine waste piles have been ranked in a similar fashion as adits including the same weighting factors, except that they are ranked by metal concentration determined by the leach test instead of load (Appendix 11A - UAA). Table 11.2 lists the top 26 mine waste sites plus an additional six sites which were added because of their large size and therefore potential for significant load contributions. Leachate concentrations presented in Appendix 10E of the UAA were converted to "potential loads". The annual load contributed from waste rock site in Table 11.2 was estimated by multiplying the concentration from the leach test of the waste rock times the surface area of the pile times the average annual runoff from the basin expressed as depth (29 inches). The potential load figures do not include any potential reductions.

The 32 waste sites listed contribute 90% of the estimated load from all 158 sites. Units are in pounds per year as opposed to pounds per day used for adits. Estimated loading from mine waste is much smaller than from adits. Approximately eighty-five percent of the mine-related annual metal load in the Upper Animas Basin is from adits, and fifteen percent is from mine waste.

As with adits, the appropriate site treatment and corresponding load reductions are based on professional judgement. Again, the estimated costs of remediation fall into the same four categories used for adits. The costs listed in Table 11.2 are the mid-point of the ranges of each category applied to the particular site.

Sites with CPDES or reclamation permits are not included in the tables in this chapter. It is assumed that required best management practices and/or treatment at these sites is already in place.

Table 11.1 Metal loads from selected adits in the Upper Animas Basin

			Pounds per day											
			High Flow						Low Flow					
Mine	**Phase 1 % Removal**	**Cost $ 1000's**	**Al**	**Cd**	**Cu**	**Fe**	**Mn**	**Zn**	**Al**	**Cd**	**Cu**	**Fe**	**Mn**	**Zn**
Cement Creek														
Mogul	80%	1000	1	0.04	1.7	14	4	2	1	0.02	0.7	5	1	3
Silver Ledge	50%	300	25	0.09	0.6	222	33	15	4	0.03	0.0	56	11	3
Grand Mogul	0%	60	15	0.15	5.3	33	10	27	1	0.01	0.2	0	0	1
Mammoth	30%	60	1	0.00	0.0	14	2	8	1	0.00	0.0	16	2	0
Anglo-Saxon	30%	60	0	0.00	0.0	15	10	2	0	0.01	0.0	15	5	1
Joe & Johns	30%	300	0	0.00	0.2	1	1	1	0	0.00	0.0	1	0	0
Big Colorado	50%	300	1	0.00	0.0	3	3	0	1	0.00	0.0	6	0	0
Porcupine	30%	60	0	0.00	0.0	14	5	1	0	0.00	0.0	10	5	1
Evelyn	50%	1000	1	0.00	0.0	2	0	0	2	0.00	0.0	3	0	0
Lewis property	50%	60	0	0.01	0.4	2	0	1	0	0.01	0.4	2	0	1
Total Cement Creek			44	0.29	8.3	320	68	57	10	0.07	1.3	113	25	12
Mineral Creek														
Kohler	50%	60	33	0.36	30.7	321	10	91	28	0.25	28.3	264	8	78
North Star	50%	300	0	0.02	0.1	6	16	4	1	0.02	0.2	6	11	3
Junction Mine	50%	300	13	0.07	2.2	126	3	14	0	0.00	0.1	3	0	0
Bandora Mine	30%	60	0	0.04	0.1	5	4	10	0	0.02	0.0	2	2	4
Upper Bonner	50%	300	1	0.00	0.0	1	1	1	2	0.01	0.0	2	1	1
Ferrocrete Mine	50%	300	2	0.00	0.0	31	5	1	3	0.01	0.0	32	7	1
Paradise	0%	60	28	0.00	0.1	246	20	2	28	0.00	0.1	246	20	2
Brooklyn Mine	30%	300	1	0.01	0.2	8	2	2	1	0.01	0.2	8	2	2
Bonner Mine	50%	300	1	0.01	0.0	1	1	1	2	0.00	0.0	2	1	0
Lower Bonner	30%	300	1	0.00	0.0	1	0	0	2	0.00	0.0	2	1	1
Little Dora	50%	300	1	0.33	0.9	5	653	48	0	0.00	0.0	0	2	0
Total Mineral Creek			81	0.85	34.3	751	715	175	65	0.31	28.9	566	54	93
Animas above Eureka														
Vermillion Mine	50%	300	0	0.04	0.2	2	1	9	0	0.01	0.1	1	0	3
Columbus	50%	300	1	0.01	0.3	3	0	9	0	0.02	0.1	1	0	4
Lower Comet	0%	10	2	0.00	0.1	2	2	1	2	0.00	0.0	1	1	1
N side of Calif. Mtn.	30%	60	4	0.01	0.0	1	5	2	4	0.01	0.0	1	5	2
Sound Democrate	50%	60	0	0.00	0.1	0	4	1	0	0.00	0.0	0	2	0
Mountain Queen	50%	300	0	0.00	0.2	1	0	1	0	0.00	0.1	0	0	0
Silver Wing	30%	0	0	0.00	0.1	0	0	0	0	0.00	0.3	1	1	1
Bagley	30%	300	0	0.01	0.0	0	13	7	0	0.01	0.0	0	6	3
Senator	30%	300	0	0.00	0.0	21	7	0	1	0.00	0.0	23	14	2
Total Animas above Eureka			8	0.08	1.0	30	33	29	8	0.06	0.7	29	29	15
Animas below Eureka														
Royal Tiger	50%	300	5	0.04	0.8	0	3	7	0	0.00	0.1	0	0	0
Pride of the West	30%	60	0	0.01	0.0	0	0	3	0	0.01	0.0	0	0	2
Little Nation	30%	300	0	0.00	0.0	9	2	1	0	0.00	0.0	4	1	0
Total Animas below Eureka			6	0.06	0.8	9	5	10	0	0.02	0.1	4	2	3
Grand Total			138	1.29	44.5	1110	822	271	83	0.45	31.0	712	109	124

Table 11.2 Metal loads from selected mine waste rock sites in the Upper Animas Basin

				Load in pounds per year					
Site Name	**Acres**	**% Reduction**	**Cost $1000**	**Al**	**Cd**	**Cu**	**Fe**	**Mn**	**Zn**
Cement Creek									
Galena Queen	1.09	90	300	154	36.8	832	6,895	0.0	6137
Kansas City #2	0.46	40	60	159	7.1	39	3,979	0.0	1172
Hercules	1.26	90	300	163	30.6	168	6,712	0.0	4711
Upper Joe & Johns	0.02	40	300	2	0.1	2	19	0.0	23
Grand Mogul - East	0.53	35	300	47	2.0	29	745	0.0	385
Kansas City #1	0.48	40	60	82	1.2	19	1,618	0.2	282
Black Hawk	0.20	50	60	82	0.5	6	124	0.1	108
Lead Carbonate	0.62	55	300	120	0.8	27	1,228	0.0	179
Henrietta 3	0.86	20	60	217	0.7	107	4,972	0.0	113
Ross Basin	0.15	10	60	9	0.3	18	234	0.0	49
Lark	0.66	90	60	18	0.8	40	886	0.0	168
Pride of the Rockies	0.05	45	60	7	0.1	0	383	0.1	7
Henrietta # 7	1.19	40	300	101	0.8	25	1,685	0.0	159
Mogul	1.16	35	300	51	1.2	32	942	0.0	261
Cement Creek Total	8.72			1,210	83.1	1,343	30,421	0.5	13,754
Mineral Creek									
Brooklyn	0.25	90	300	58	0.8	8	993	117	118
Bullion King:Lower	0.86	90	300	641	6.0	14	9,945	190	629
Upper Browns Trench	0.11	40	10	27	0.1	8	198	3	9
Congress Shaft	0.35	40	60	11	0.2	16	109	11	20
Brooklyn Upper	2.57	20	60	661	3.1	38	9,909	176	163
Upper Browns	0.51	90	60	82	0.3	5	1,610	6	25
Little Dora	1.39	30	300	94	0.4	43	452	471	66
Brooklyn Lower	0.86	20	60	110	0.6	9	672	122	105
Mineral Creek Total	7			1,684	11.5	142	23,888	1,095	1,135
Animas above Eureka									
Ben Butler	0.34	40	300	28	0.8	8	225	1	165
Silver Wing	1.21	50	60	98	1.0	123	393	172	131
Tom Moore	0.19	90	60	15	0.3	1	8	43	73
Eagle	0.07	90	60	1	0.1	1	0	7	18
Lucky Jack	0.70	90	60	16	0.6	3	14	32	95
Animas above Eureka Total	3			157	2.8	136	639	256	482
Animas below Eureka									
Clipper	0.09	90	60	6	0.2	7	80	57	70
Buffalo Boy	0.38	90	60	17	0.8	24	13	73	141
Ben Franklin	0.37	90	60	81	0.4	13	612	99	95
Caledonia	0.57	30	60	23	1.0	15	1	50	255
Sunnyside	2.50	90	1,000	40	2.3	10	0	536	664
Animas below Eureka Total	4			168	4.6	69	706	815	1,224
GRAND TOTAL	22			3,219	102	1,691	55,655	2,167	16,595

V. REMEDIATION SCENARIOS

Using the characterization and ranking of sites, the effects of remediating multiple sites can be estimated. This chapter compares several different remediation scenarios including costs. The scenarios help determine what metal loading may be "reversible" versus "irreversible". Natural sources of metals are considered irreversible. Some human-related sources could also be called irreversible if they are very difficult and expensive to change. There is the issue of how cost-effective these changes may be and whether or not they would have a noticeable impact in protecting aquatic life.

Figures 8.18 to 8.21 of the Animas UAA show the levels of Al, Cd, Cu, Fe, Mn, and Zn from adits and mine waste. These figures show the maximum amount of each of the six metals that has been identified with mining-related activities. Most remediation methods will remove only a portion of these metal loads.

Section III of this plan discussed the methodology that was used to rank and prioritize specific adits and mine waste piles in the Basin, and discussed relevant technology that could be used to remediate those sources. Cost estimates and amount of reduction corresponding to different technologies are comparable to the actual remediation costs already encountered by SGC, the ARSG, and others in the Basin. (See Chapter 3, Table 3.1 of the UAA).

The ARSG technical work group estimated the potential reductions in loading (as a percentage reduction) that could be achieved by implementing remediation technologies at each adit and mine waste site. Estimated loads contributed by each of 174 adits and 158 waste rock sites are shown in Appendix 11A of the UAA. Of those sites, load reductions, applicable treatment technology, remediation option recommendations and cost estimates have been derived for 78 adits and 127 mine waste sites. Those sites that were not included contributed negligible loading, are a substantial distance from streams, and would not be cost-effective to remediate.

Treatment of adits is divided into two phases. The first phase treatments are generally simpler and lower cost. They would be applied initially and evaluated for effectiveness. The first phase also includes more detailed investigations of complex adits, such as the Paradise portal on the Middle Fork of Mineral Creek. Although costs would be incurred, no improvements would be anticipated for these few specific sites. Phase 2 treatments would be implemented if phase 1 treatments proved partially or completely unsuccessful. These additional treatments are generally more costly but should be more effective in reducing metals.

The estimated cost of remediation of each site is listed as a range in Appendix 11 of the UAA (and Appendices 10E and 10F). For average costs see Table 11.1 and 11.2 of this Plan. Estimates are based on professional judgment given the technology that could be used and the size and complexity of the site. Accessibility affects both cost and the remediation technique selected.

As discussed in Section II of this plan, the cost analysis is a first approximation and uses four cost categories, each with a broad numerical range. The costs for remediation for each site listed in Table 11.1 below is the mid-point of the range for each cost category. One million dollars was used as an estimate for sites whose costs are greater than \$500,000. These cost estimates do not include engineering design, operation, or maintenance costs that may be needed.

Metal Reduction Scenarios

Using the information from Tables 11.1 and 11.2 and Appendix 11A of the UAA, the results of several different remediation scenarios can be estimated. The scenarios shown on Table 11.3 include phase 1 treatment of the top 33 adits and of the top 78 adits, phase 2 treatment of the top 33 adits and of the top 78 adits, phase 1 treatment of the top 32 mine waste piles and of the top 127 mine waste piles. Costs listed under phase 2 include the costs of both phase 1 and phase 2 treatments since phase 2 would not be implemented until after phase 1 had been tried.

For the adit scenarios, loading figures are derived from low-flow samples because that time period is of most concern. Out of 174 adits sampled, only 133 had measurable drainage during low-flow samplings.

The cost estimates listed on the tables above and in Appendix 11A of the UAA do not include engineering design, operation, or maintenance costs. Remediation experience in the Basin has shown that administration costs are substantial and cost overruns have been encountered owing to larger than expected volumes of material or other unanticipated problems. The scenarios listed below include a 30% administration cost and a 20% contingency cost added to the sum of the individual site costs.

Table 11.3 Summary of metal loads from adits and combined mine waste for the Animas Basin above A72.

	Adits Low flow loads		Mine Waste	
	Total load of Al, Cd, Cu, Fe, Mn and Zn in pounds/year			
Top 33	386,741		Top 32	79,429
173 Adits[1]	434,547		Top 158	88,602
	Estimated cost to remediate in $1000's			
	Phase 1	Phase 2		Option 1
Top 33	$ 12,105	$ 20,550	Top 32	$ 8,175
Top 77	$ 20,550	$ 31,830	Top 127	$ 21,960
	Load Removed in pounds/year			
	Phase 1	Phase 2		Option 1
Top 33	128,041	194,275	Top 32	50,494
Top 77	138,834	208,945	Top 127	54,618
	Cost pound/year			
	Phase 1	Phase 2		Option 1
Top 33	$ 94.54	$ 105.78	Top 32	$ 161.90
77 Adits	$148.01	$152.34	Top 127	$ 402.10

*Total cost divided by load removed.

Clearly there are diminishing returns in treating both adits and mine waste. The top 33 adits account for 89% of the load and under phase 1, it would cost $12.5 illion to treat them. To treat the additional 11% of the load would add $8.5 million. The contrast is more stark under mine waste. The top 32 sites account for 90% of the load and would

[1] Revised 7/15/01 from 133 adits

cost just over $8 million to treat. Treating the additional 10% would add almost $14 million.

The phase 2 adit scenario includes removal of large quantities of Fe and Al from the Paradise portal. In fact, 81% of the difference in load removed between phase 1 and phase 2 for adits can be attributed to phase 2 remediation of the Paradise alone. Under phase 1, no reductions in metals from the Paradise are anticipated because a more thorough investigation of the site will be the first step. With the exception of this one site, there is little difference in reductions of metals between phase 1 and phase 2. Moreover phase 2 would only be implemented if phase 1 did not result in projected reductions. Therefore, without the Paradise and its associated phase 2 remediation costs of $1 million, the difference in costs between phase 1 and 2 can be thought of as a range of costs associated with a total loading reduction for adits of approximately 170,000 to 180,000 pounds per year.

Remediating the Paradise portal and another site, the Ferrocrete mine, is problematic. They are both shallow workings in the Mineral Creek drainage and lie near the base of valleys. The mines are thought to have intersected the relatively shallow groundwater that wells up at valley bottoms creating the area's infamous iron seeps and bogs. Metal loading may well be the result of natural geological processes that is carried <u>into</u> the mine through groundwater infiltration. While treating naturally occurring source loads (coming from adits) may be beneficial, discharges with high iron and aluminum concentrations are expensive to treat because of high production of sludge which needs disposal plus frequent system maintenance. These adits are also collapsed, indicating that they were constructed in highly fractured rock making it unlikely that bulkhead seals would provide significant reductions. Successful remediation of these sites would be very difficult and expensive.

Effects of Remediation on Water Quality

Figure 11.1 shows the estimated reductions of the six priority metals at the four gages if remediation was implemented on the top 32 mine waste piles and phase 1 remediation was implemented on the top 33 adits. Figure 11.2 shows estimated reductions if remediation was implemented on the top 32 mine waste piles and phase 2 remediation was implemented on the top 33 adits. The description below summarizes the results.

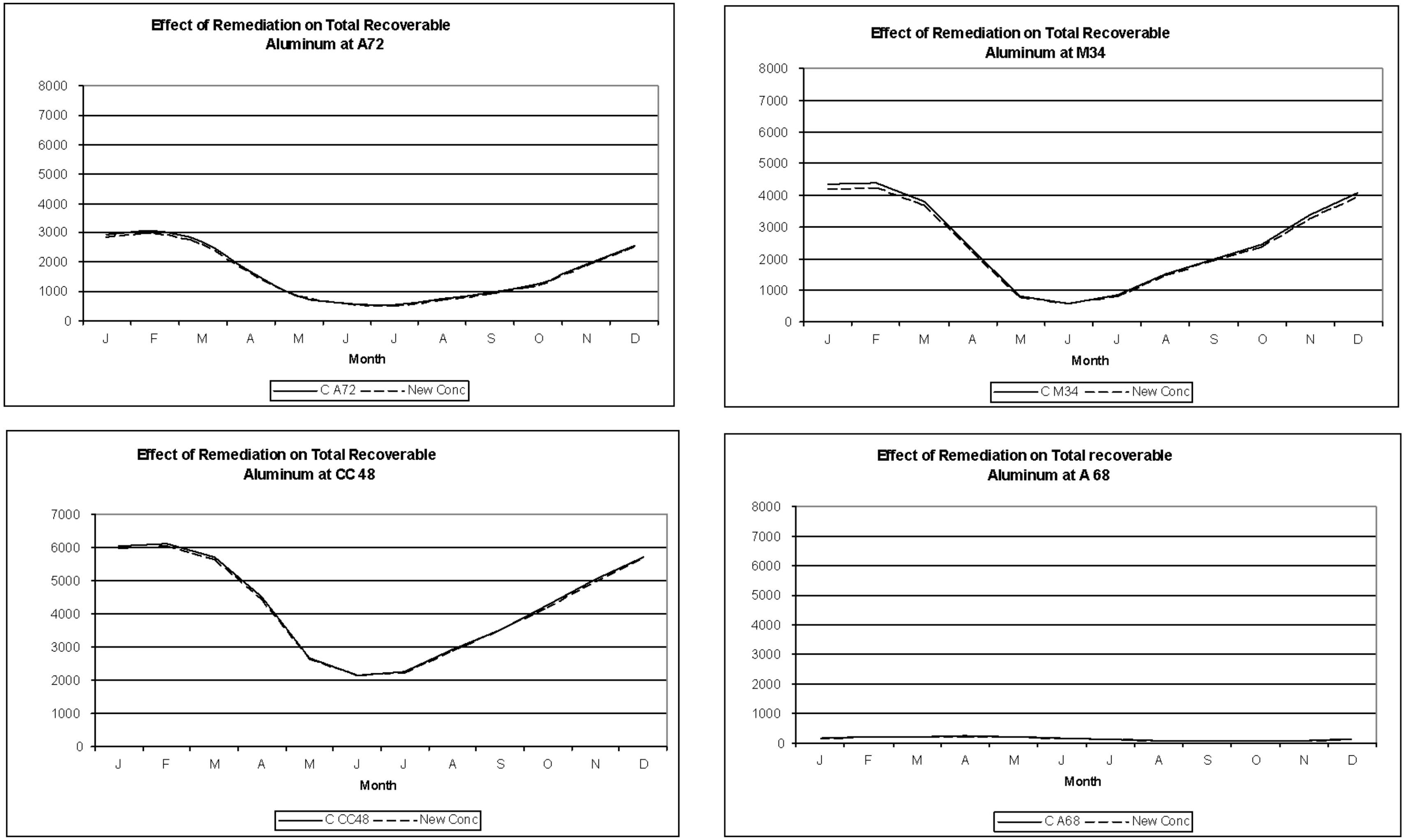


Figure 11.1.a Expected concentration in micrograms per liter of total recoverable aluminum if phase 1 for priority adits and priority waste rock sites are remediated.

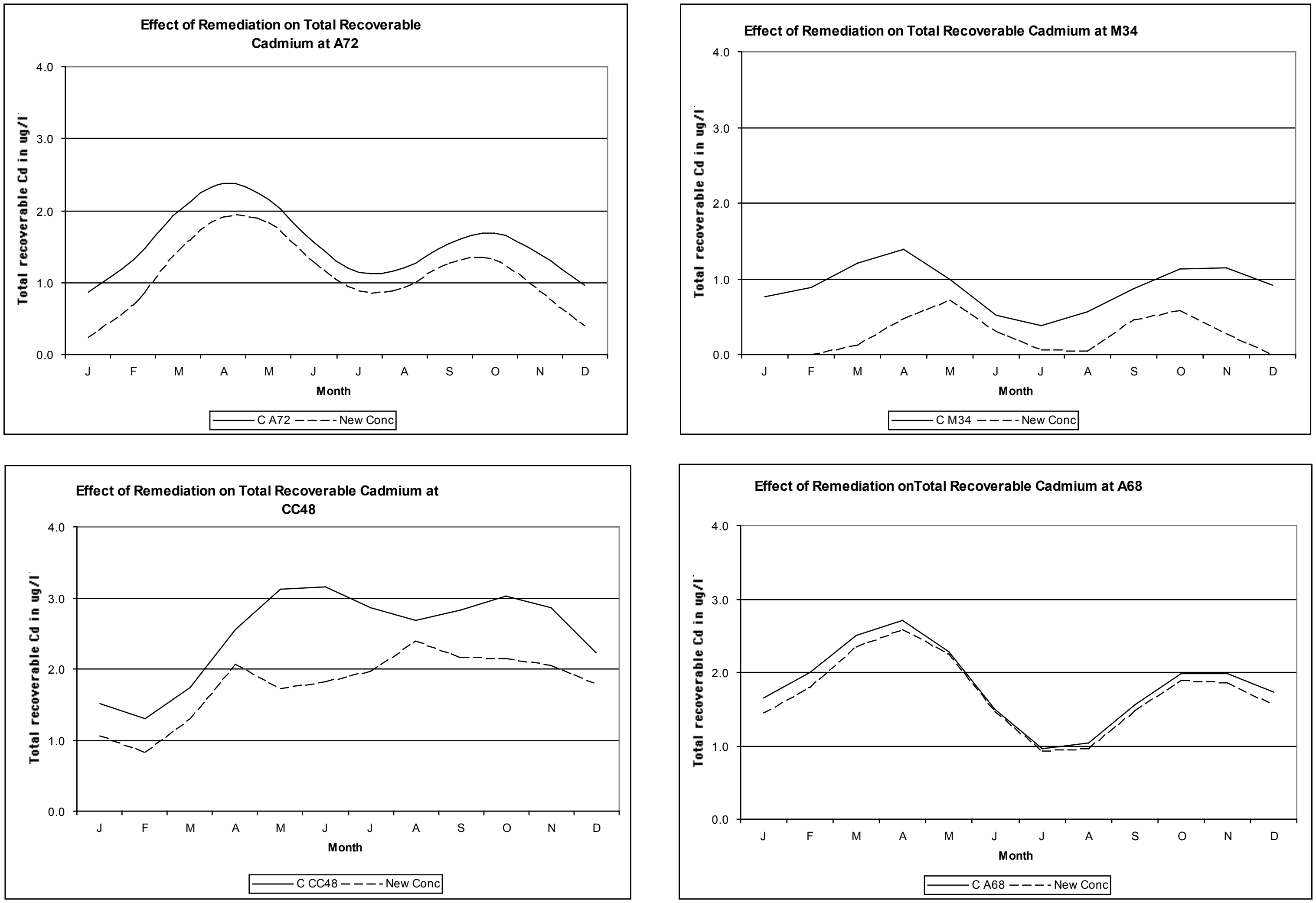
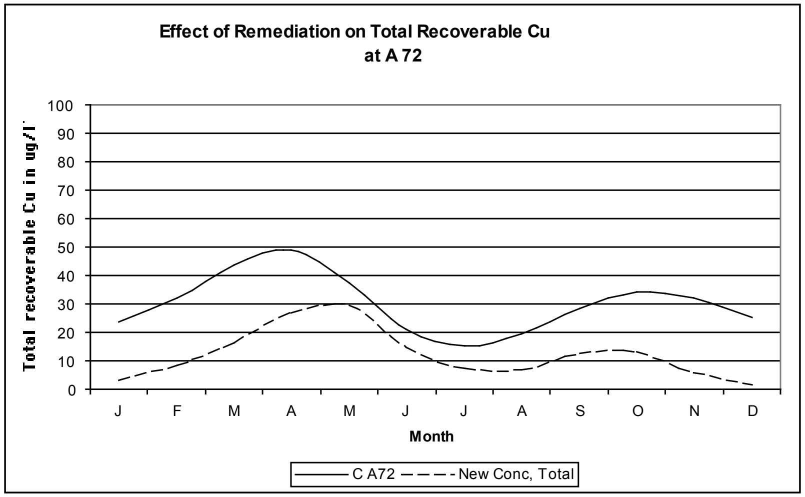
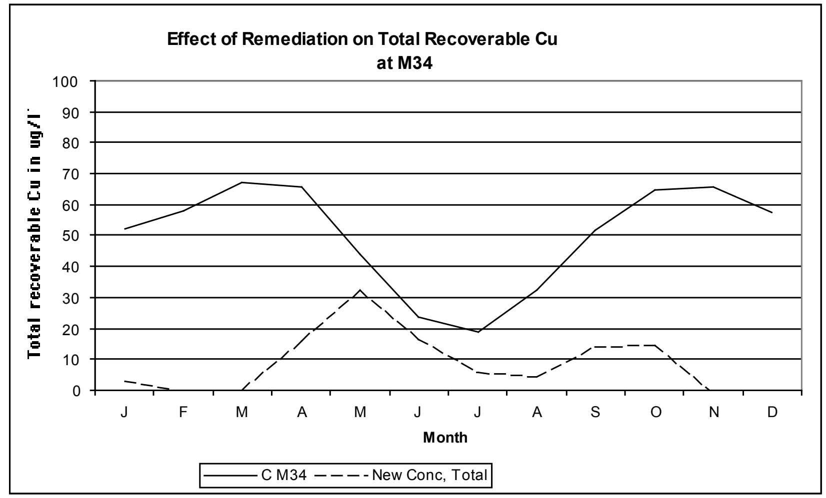
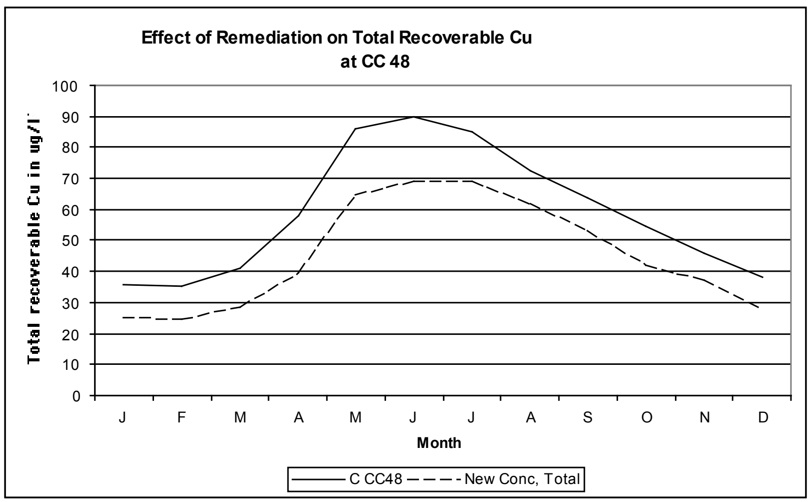


Figure 11.1.b Expected concentration in micrograms per liter of total recoverable cadmium if phase 1 for priority adits and priority waste rock sites are remediated.







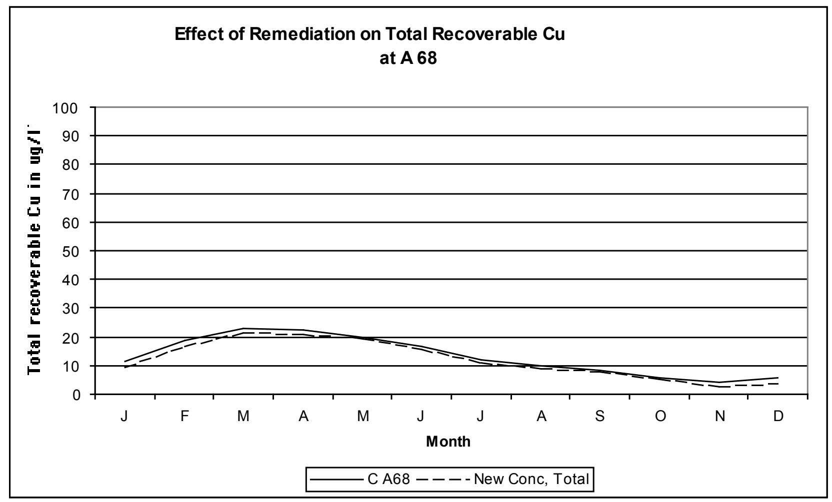
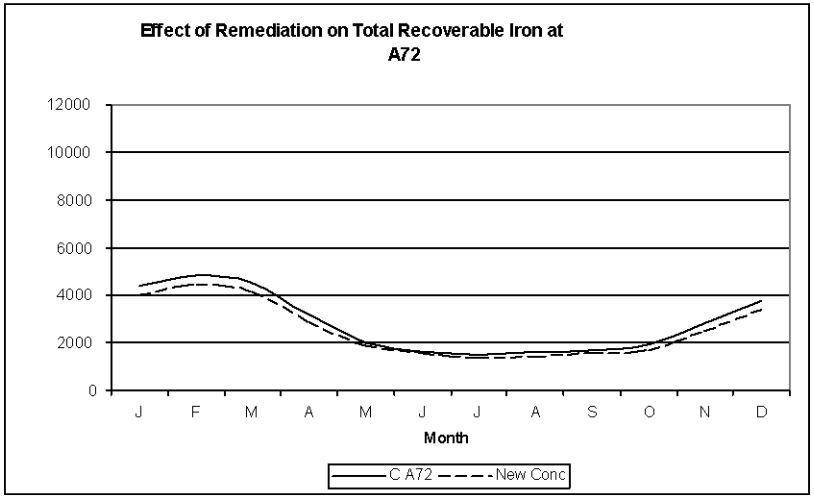
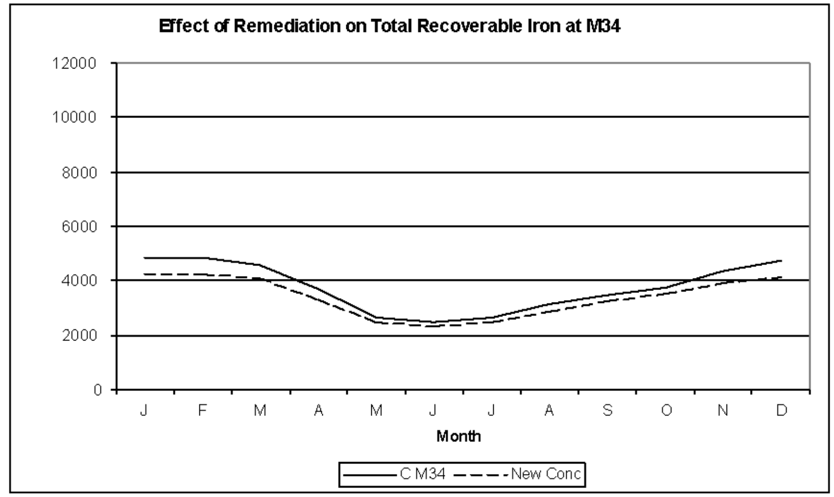
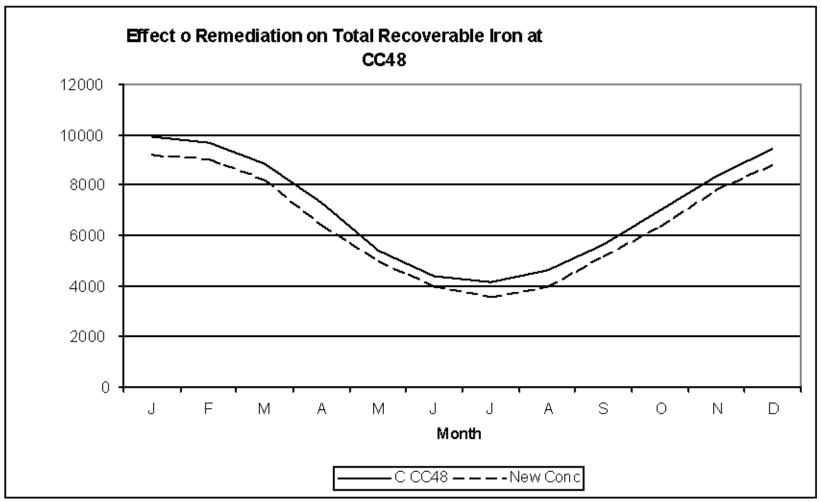


Figure 11.1.c Expected concentration in micrograms per liter of total recoverable copper if phase 1 for priority adits and priority waste rock sites are remediated.







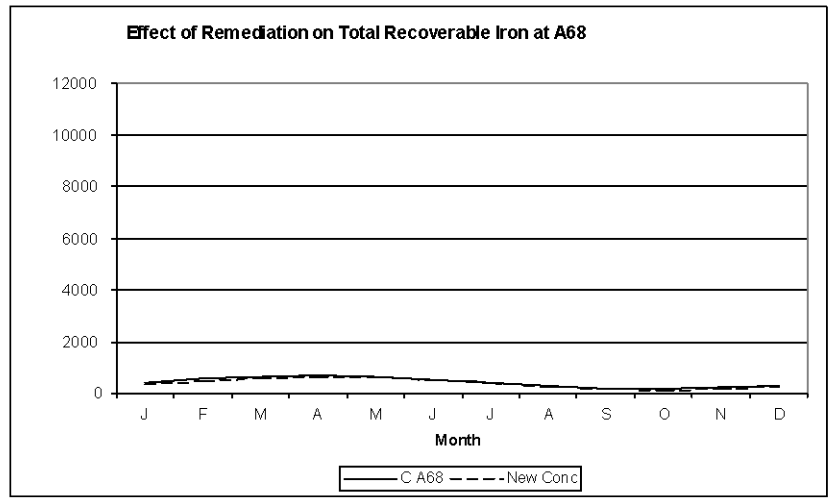


Figure 11.1.d Expected concentration in micrograms per liter of total recoverable iron if phase 1 for priority adits and priority waste rock sites are remediated.

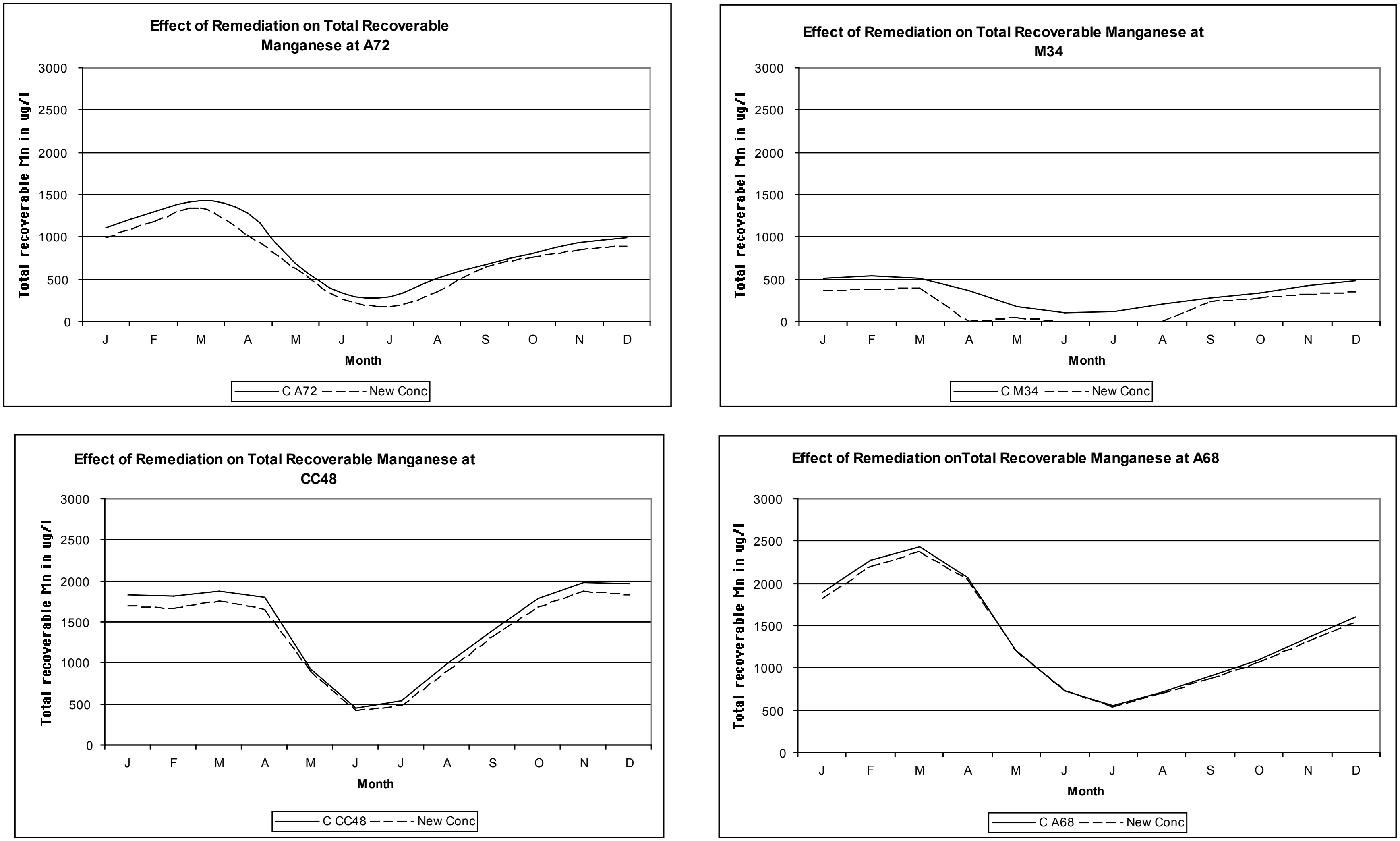


Figure 11.1.e Expected concentration in micrograms per liter of total recoverable manganese if phase 1 for priority adits and priority waste rock sites are remediated.

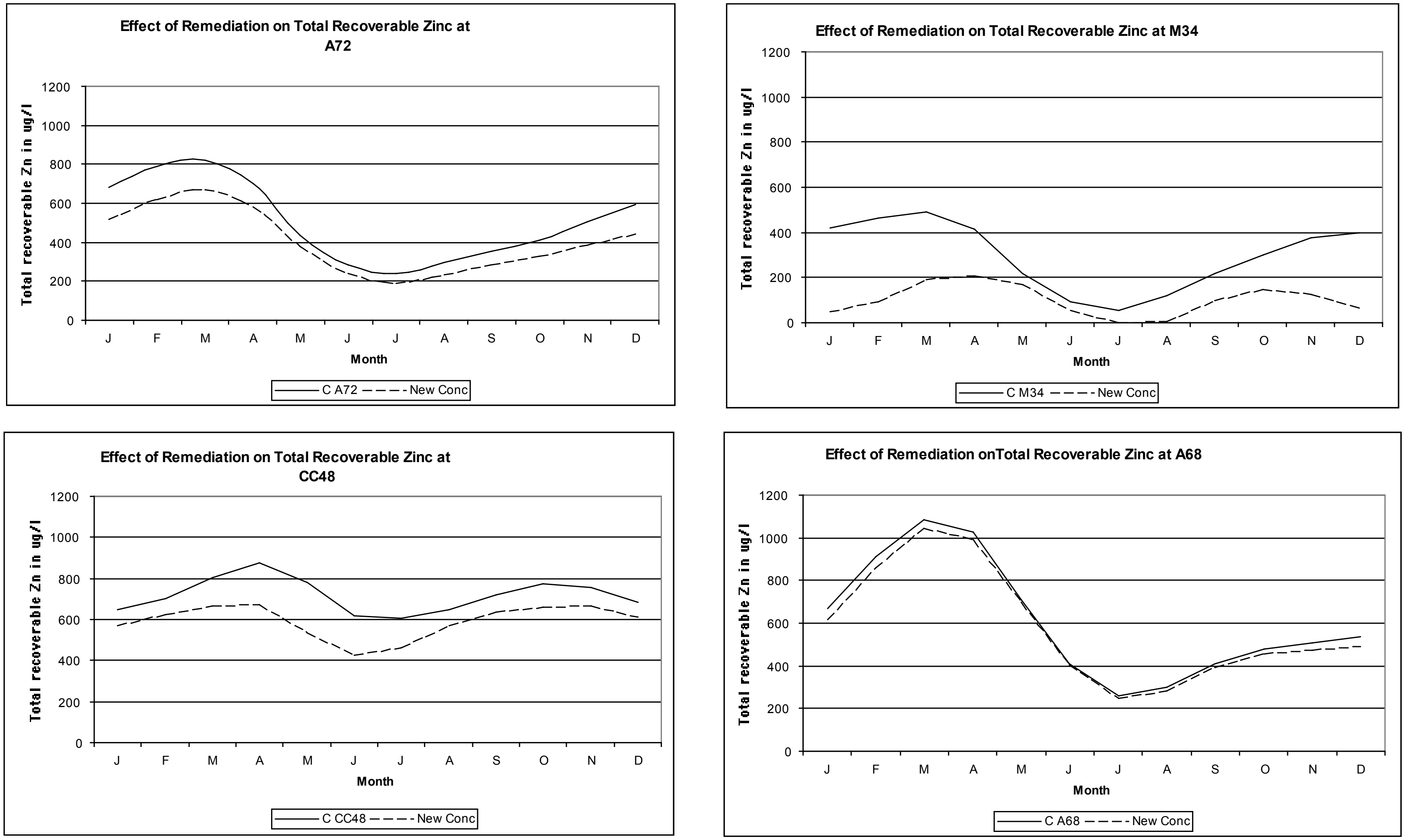


Figure 11.1.f Expected concentration in micrograms per liter of total recoverable zinc if phase 1 for priority adits and priority waste rock sites are remediated.

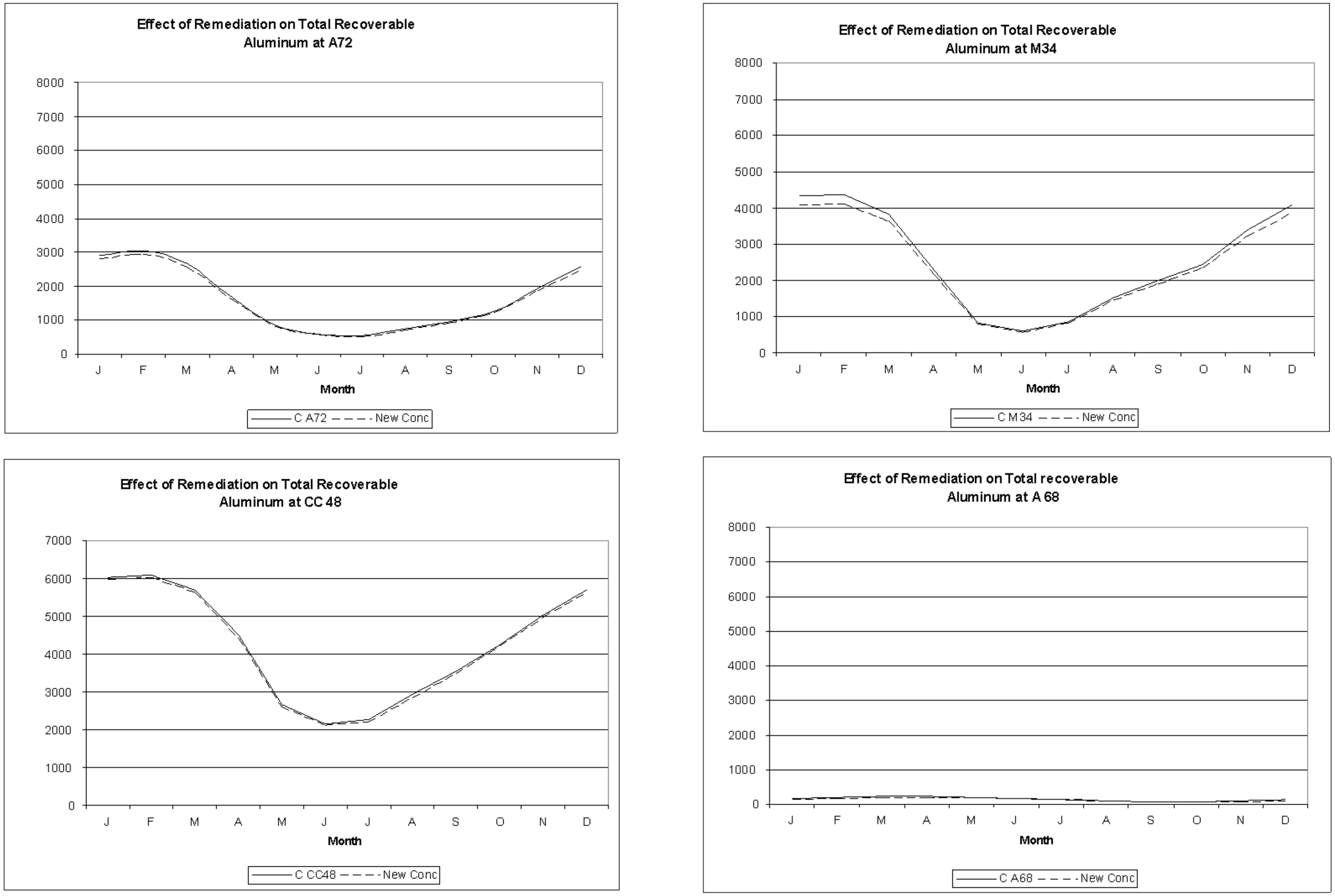


Figure 11.2.a Expected concentration in micrograms per liter of total recoverable aluminum if phase 2 of the priority adits and combined mine waste sites are remediated.

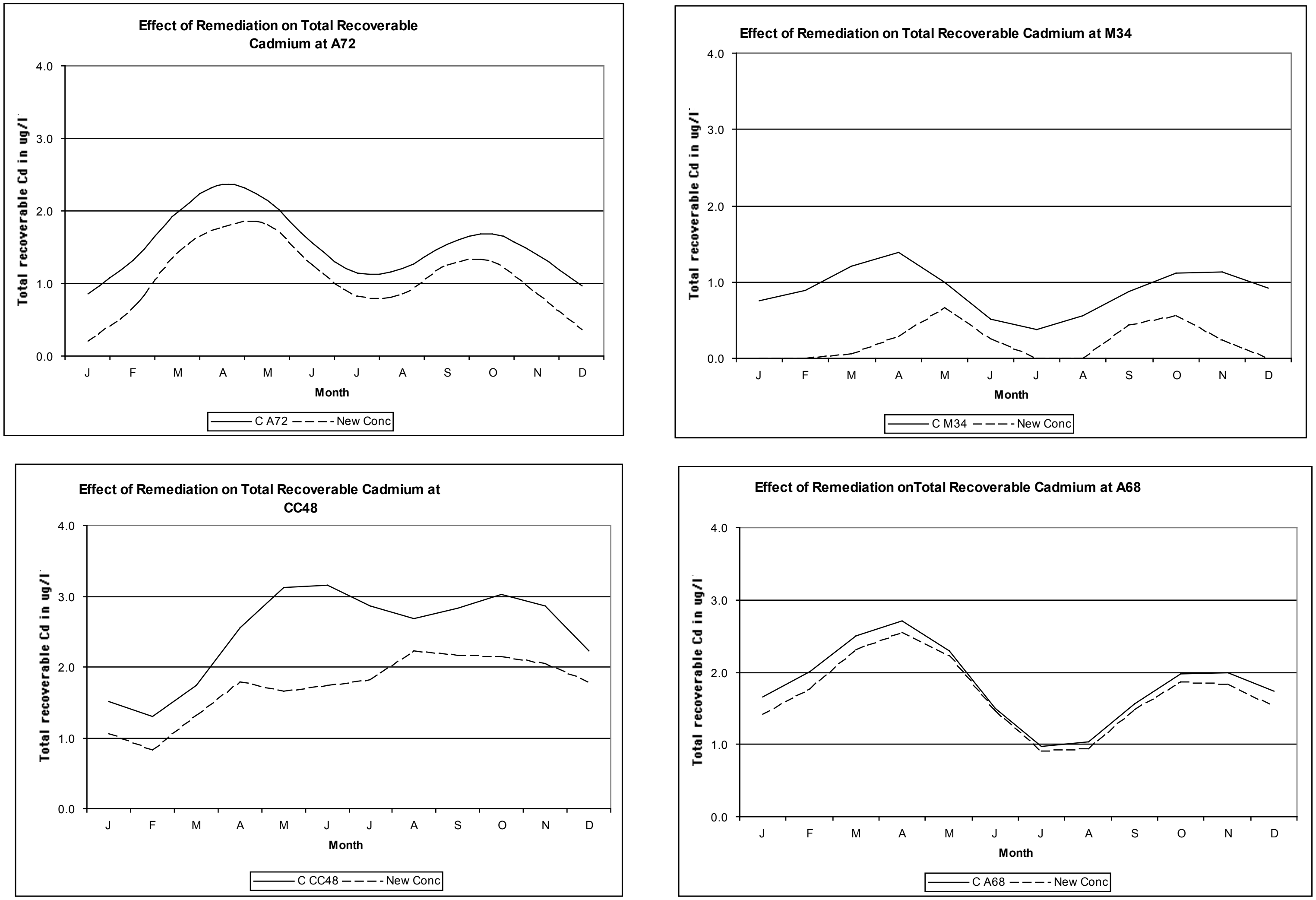


Figure 11.2.b Expected concentration in micrograms per liter of total recoverable cadmium if phase 2 of the priority adits and combined mine waste sites are remediated.

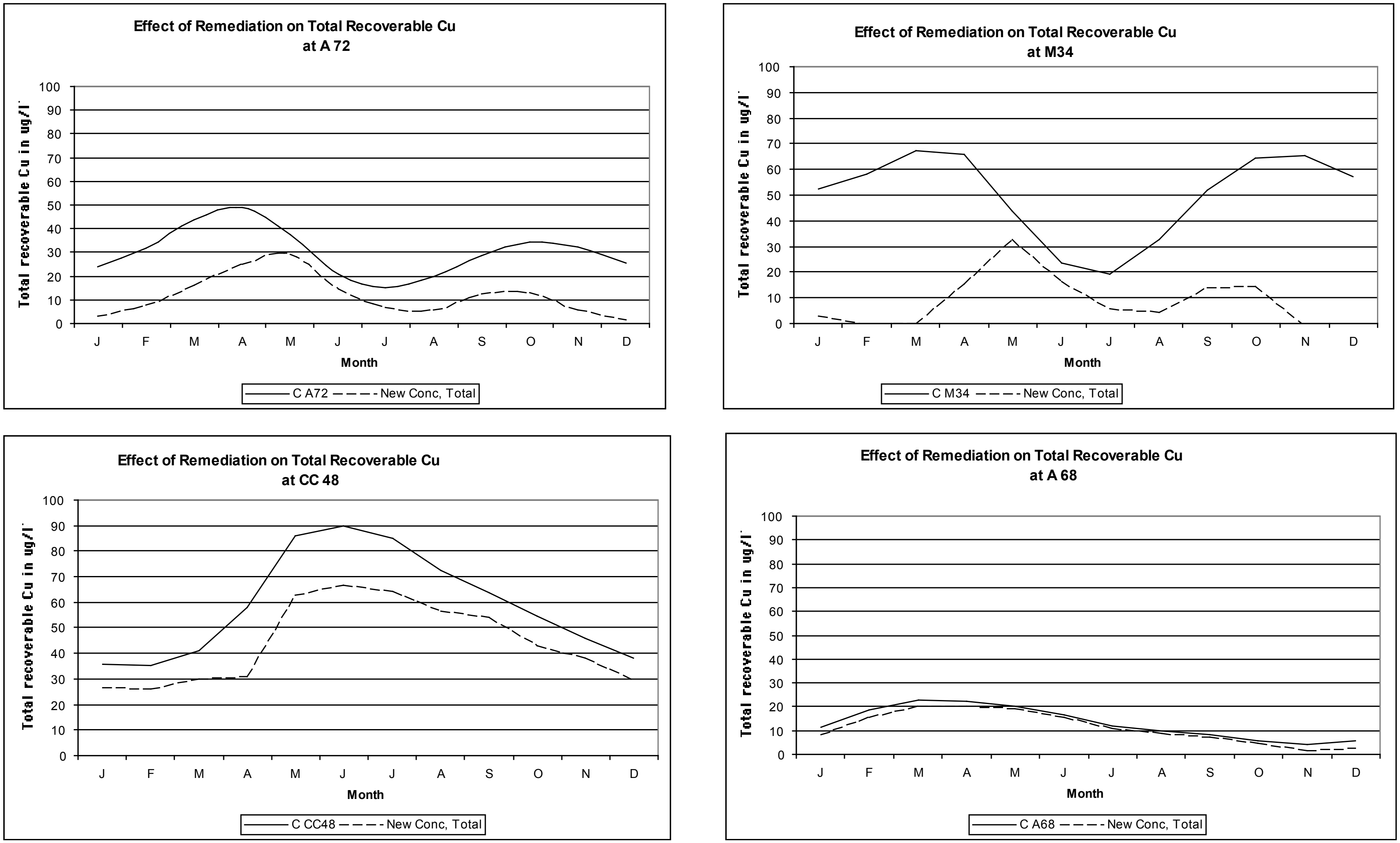


Figure 11.2.c Expected concentration in micrograms per liter of total recoverable copper if phase 2 of the priority adits and combined mine waste sites are remediated.

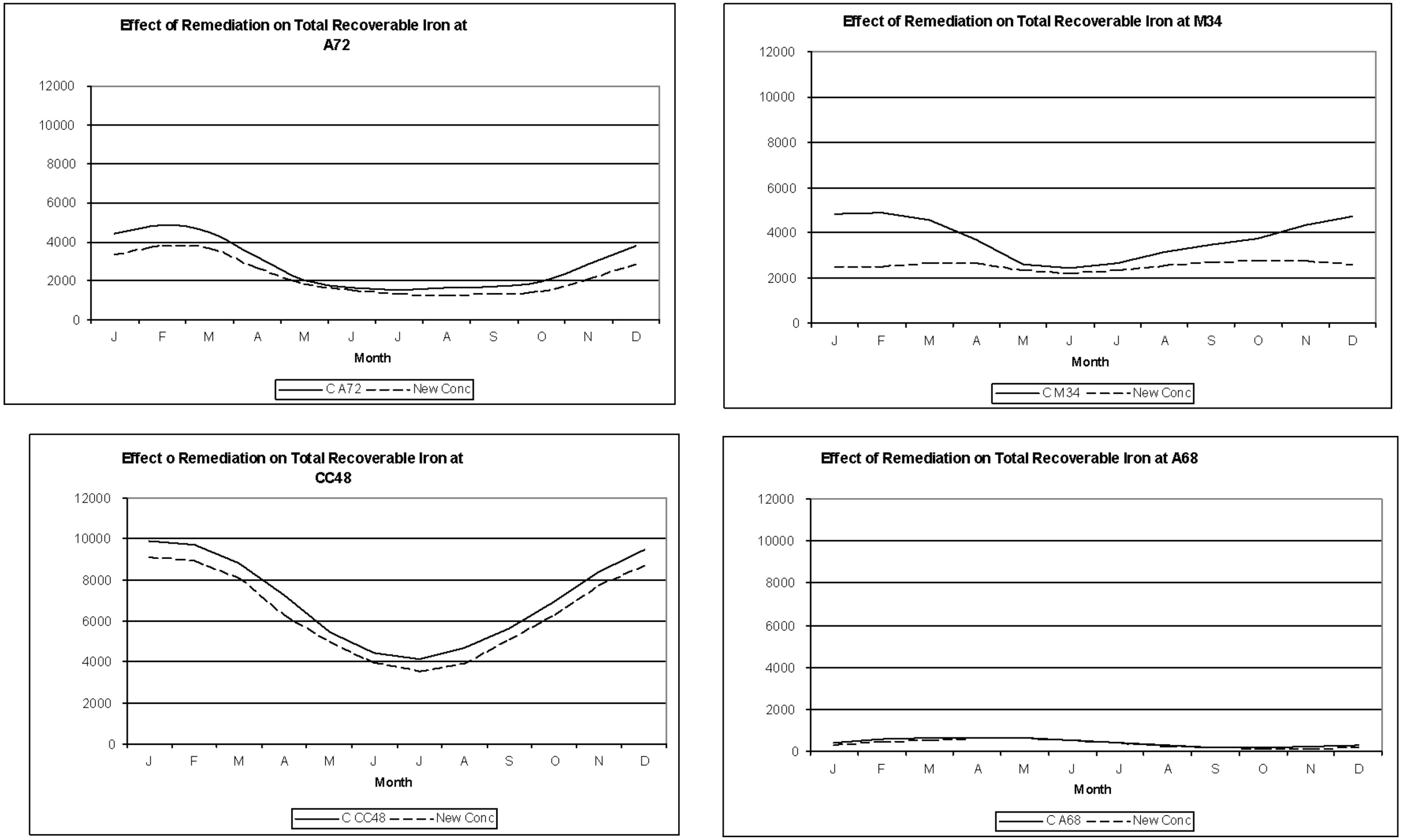


Figure 11.2.d Expected concentration in micrograms per liter of total recoverable iron if phase 2 of the priority adits and combined mine waste sites are remediated.

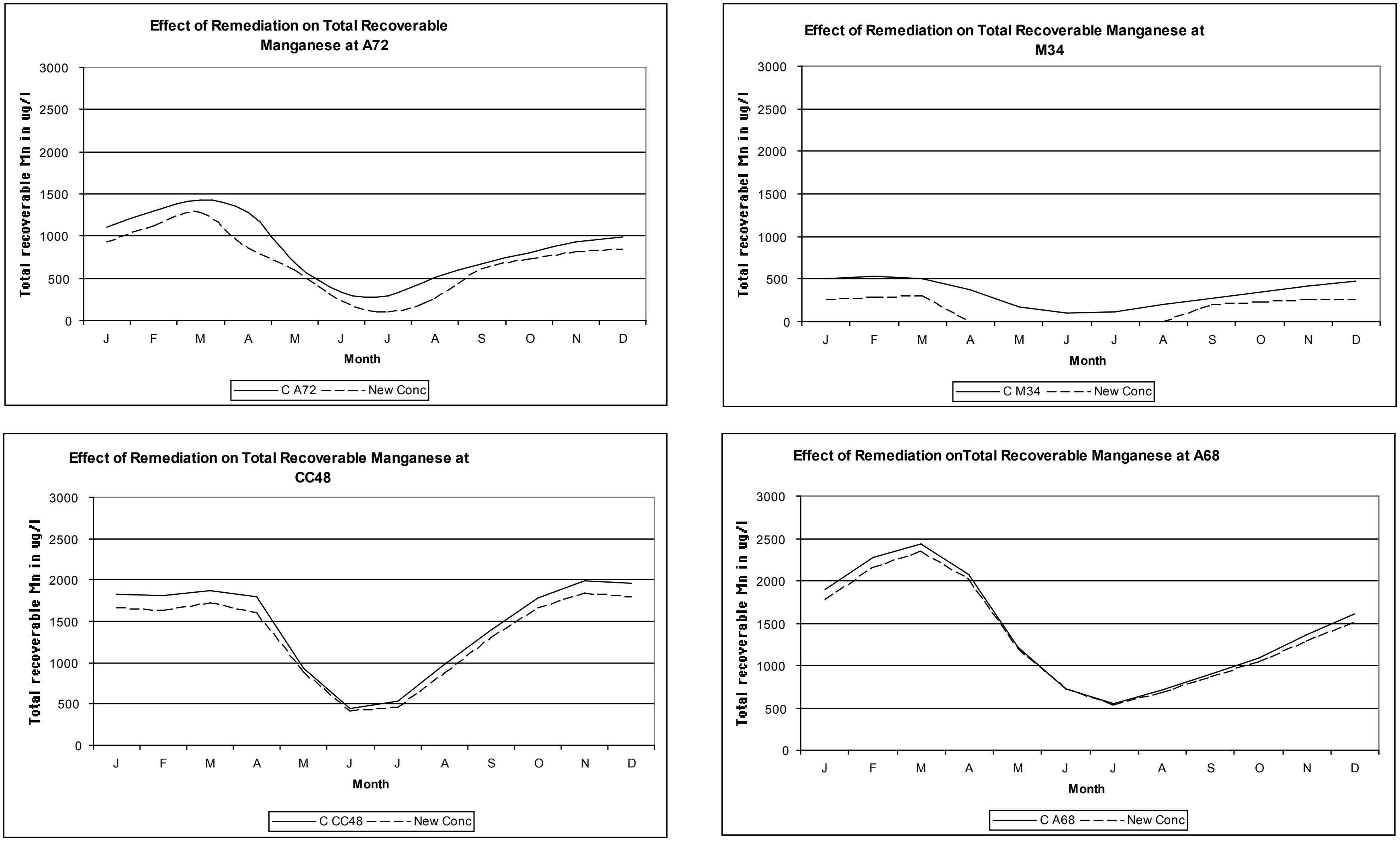


Figure 11.2.e Expected concentration in micrograms per liter of total recoverable manganese if phase 2 of the priority adits and combined mine waste sites are remediated.

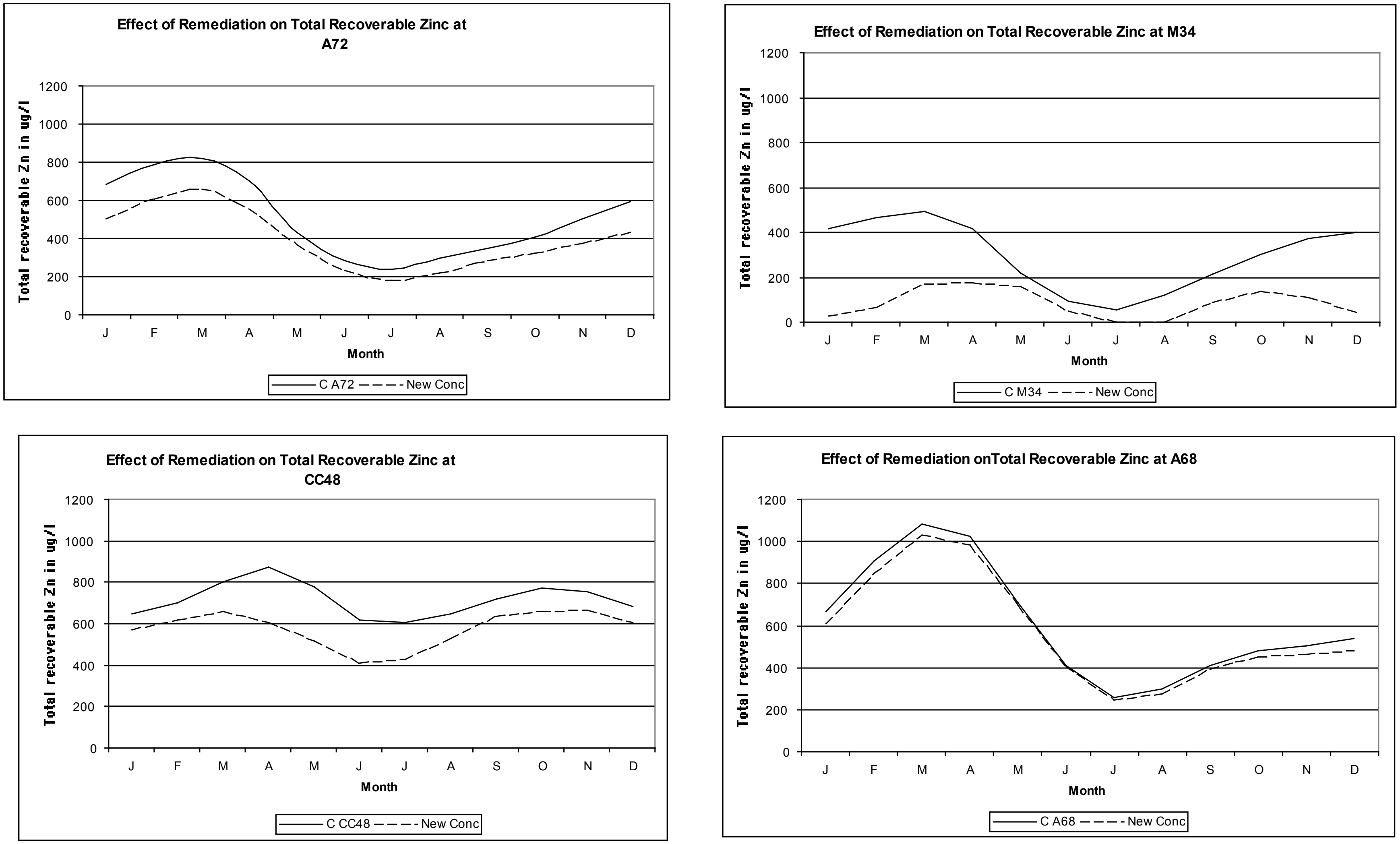


Figure 11.2.f Expected concentration in micrograms per liter of total recoverable zinc if phase 2 of the priority adits and combined mine waste sites are remediated.

Animas above Silverton, A68

Remediation of combined mine waste and either the phase 1 or phase 2 adit scenarios will have very little effect on reducing the concentration of Al, Cd, Cu, Fe, Mn, or Zn at A68. Cd and Mn will continue to exceed chronic TVS under the average stream flow condition in the late winter and early spring. Zn will continue to exceed both acute and chronic TVS year-a-round. Cu, when corrected for the dissolved fraction, should meet TVS. Al and Fe meet aquatic life TVS criteria.

A substantial amount of Cd, Mn, and Zn enters the Animas River from unidentified, diffuse sources between Arrastra Gulch and A68. The largest tailings piles (previously ponds) in the Basin lie near the river along this stretch. The site is permitted and has undergone extensive remediation work over the past ten years. In the fall of 1999, a trench was dug to bedrock above the tailings, and a barrier and drainage system was installed to capture groundwater flow that might enter the piles. Data collected after 1999 was not used for the UAA. Therefore, the impacts of the most recent remediation work are unknown. In addition, it is doubtful that one year's data would be enough to identify changes in water quality due to these actions. Given the minimal remediation potential identified upstream, an evaluation of the "reversibility" of the load of Cd, Mn, and Zn that enters the Animas River between Arrastra Gulch and A68 will be needed to determine if water quality can be substantially improved at A68. This is currently under investigation (NPS 319 Segment 3a Characterization Project).

Cement Creek at Silverton, CC48

Remediation of combined mine waste and the phase 1 adit scenario should reduce levels of Cd, Cu, and Zn below levels encountered in Cement Creek before SGC began treatment of upper Cement Creek at the Gladstone treatment plant. Implementation of the phase 2 scenario in Cement Creek will have only a small beneficial effect beyond phase 1 on the concentration of Cd, Cu, and Zn at CC48, unless phase 1 is significantly unsuccessful. Figures 11.1d and 11.1e indicate that either the phase 1 or phase 2 remediation scenario will have little effect on levels of Fe or Mn. Remediation will have no effect on the level of Al. Concentrations of all six metals will remain above both acute and chronic TVS for aquatic life. Metal reductions will benefit downstream segments of the Animas River however.

Mineral Creek near Silverton, M34

Remediation of combined mine waste and the phase 1 adit scenario should reduce levels of Cd, Cu, and Zn to concentrations that meet chronic TVS during average stream flow. The current level of Mn is less than TVS for aquatic life. Implementation of phase 1 reductions should lower the level of total recoverable Fe, however it will continue to exceed aquatic life TVS year-a-round. This analysis shows that remediation is not expected to measurably change the concentration of dissolved recoverable Al, which will continue to exceed acute TVS criterion during the winter. Implementation of phase 2 reductions will primarily lower levels of total recoverable Fe, however, Fe will continue to be higher than TVS for aquatic life.

Animas River below Silverton, A72

Remediation of the combined mine waste and the phase 1 adit scenario should reduce levels of Cd, Cu, and Zn during average stream flow. Cd and Cu concentrations will be close to chronic TVS for aquatic life but may exceed those criteria in the spring. Zn will continue to be at a level that exceeds both acute and chronic TVS for aquatic life year-a-round. Fe and Mn concentrations may be slightly lower, however, total recoverable Fe will continue to exceed TVS year-a-round. Mn currently is lower than the TVS. Neither phase 1 nor phase 2 remediation is expected to have much effect on the current level of dissolved Al. Aluminum would continue to be a limiting factor. If a sufficient amount of the load of Cd, Mn, and Zn that enters the Animas River between Arrastra Gulch and A68 can be "reversed," further improvements in those constituents should be seen at A72.

Reductions in pH

Current TVS for pH is 6.5 to 9.0. pH is a measurement of hydrogen ions based on a logarithmic scale (base 10) so that a whole number increase, from 5.0 to 6.0 for example, signifies a ninety percent reduction in the concentration of hydrogen ions. The presence of iron is a major factor in determining pH.

In winter, pH is 6.1, 5.5, and 4.8 for segments 3a, 4a, and 9b respectively. Attempts were made to model potential improvements in pH due to remediation, but they were unsuccessful. Because of the low potential reductions identified for iron above A68, it is uncertain whether pH will be improved. The possibility of improving pH is higher at M34 and A72, because of the potential for reductions in iron loading, but the amount of improvement is probably quite small. Reaching the TVS standard is highly unlikely.

Remediation Summary

Completion of the proposed remediation projects will result in TVS being met at several locations for some but not all metals. It is impractical to meet TVS at all locations. This is due to the large amount of natural metal and acid production throughout the Upper Animas watershed. This problem was evidently realized when the Clean Water Act was passed as it requires that aquatic life standards be met, as a minimum, <u>if practical to do so</u>. The Animas Watershed Plan is designed to be a practical attempt to meet the requirement. There currently is no plan to treat naturally occurring metal and acid contributions. The Animas UAA, plus other information developed during WQCC triennial review period, demonstrates significant improvement to water quality and aquatic habitat will result in an improved fishery and associated aquatic life. While Cement Creek is expected to remain devoid of life, the Animas main stem is expected to sustain a brook trout fishery immediately below Silverton (Segment 4a) and four species of trout below Elk Park (Segement 4b). Many streams will witness improved benthic macroinvertebrate life. New stream standards and use classifications have been adopted by the WQCC that reflect the reductions anticipated from the remediation envisioned in this plan, plus the biological potentials of the receiving streams.

VI. REMEDIATION FUNDING AND TECHNICAL ASSISTANCE

Total funding for the remediation planned is estimated to be $30 million in 2001 dollars. This does not include the remediation already accomplished by 2001, estimated to be approaching $20 million.

Funding of non point source remediation of mine waste sites will likely come from the NPS 319 program, in kind matches from various sources, FLMA and partnerships between landowners, previous operators, and other funding entities. For instance, in 2004 a project to remediate the Henrietta 6 & 7 level mine wastes is being jointly funded by the BLM and Duke Energy (or its subsidiary).

Several thousand tons of the highest metal bearing mine wastes has been sent to the Howardsville mill for ultimate disposal in a permitted facility.

Most remediation costs are associated with point source discharges of mine drainage. On occasion is may be possible to reduce or eliminate inflows to a mine thus minimizing the need to treat discharging water. ARSG currently has a NPS 319 Infiltration Control Project that is having success with this endeavor. However, the majority of discharging mines will likely either require expensive treatment of the effluent or placement of a hydrological seal (bulkhead) within the mine. It is unlikely that NPS funding can be used for either of these situations since they are considered point sources. Unfortunately present regulations are structured such that a party trying to remediate a discharge could be considered an operator and inadvertently take on additional liability for the remaining metal discharge beyond what is practical or intended to be treated. Therefore the ARSG has developed its own pilot project legislation that would provide “Good Samaritan” status that could eliminate this undo burden. Included in the bill, sponsored by Rep. Scott McInnis, is an appropriation request of $5 million to begin addressing draining mines in the Animas watershed. Additional appropriation requests are optional.

As in the case of non-point sources, some priority draining mines are either wholly owned or owned in part by FLMA. FLMA remain committed to provide funding and expertise for these cleanups and will partner with other entities such as potentially responsible parties, other landowners, and the ARSG to address these sites.

Technical assistance has been continuously provide by the many ARSG participants which include water experts, an ecologist, mining engineers, a civil engineer, and access to the staffs of DMG, CGS, USBLM, USFS, and USBOR.

VII. MONITORING

The ARSG intends to provide continuing monitoring programs to evaluate short and long term remediation impacts. They will ensure the short term monitoring of individual projects they sponsor, as a requirement imposed by the funding entity. In addition, the stakeholders have a long-term interest in monitoring at and below the four stream gauges in Silverton to determine the more widespread benefits of remediation activities to the watershed. It is hoped that funding will continue to be provided such that biomonitoring for select sensitive species of aquatic life, plus geochemical monitoring at the four gauging stations will continue indefinitely. Every five years a fish and benthic macroinvertebrate survey should be performed and analyzed for the entire basin.

VIII. EDUCATION

The ARSG is an entity interested in engaging the public and government agencies in making progress in meeting the goals of improved water quality and aquatic habitat throughout the basin. We intend to continue our ten year tradition of holding open public monthly meetings as well as special work group meetings as necessary. We make all information readily accessible to the public as printed materials in the Silverton library and at the offices of the Coordinator and San Juan RC&D. Electronic digital information is available on CDROM, floppy disk, and through our web site at waterinfo.org/arsg/. Many presentations are made both locally and regionally concerning our progress, methods, technology evaluation, successes and failures. Recent biomonitoring techniques and remediation project results were presented at the Mountain Studies Institute's annual 'State of the San Juan's conference and at an abandoned mines conference at the Center for the American West. Several presentations on progress are planned at Fort Lewis College and throughout Durango. ARSG participants frequently provide educational opportunities at the Silverton school which is using a mountain oriented 'Outward Bound' curriculum. We have made several videos, some of which regularly play on local TV stations and at regional film festivals. We will continue to engage the public through these and other methods. A primary goal is to develop a local sense of stewardship for the watershed.

IX. SCHEDULE

The stakeholder process will serve to prioritize sites for remediation, encourage remediation, advance technologies, and provide resource opportunities. However, public and private landowners and/or those responsible parties will ultimately be legally responsible and most often be project proponents. ARSG will implement demonstration projects to further encourage watershed improvement and test new technologies. Given the enormous size of the basin and high number of mine sites, remediation and recovery efforts could take as long as 20 years. It is hoped that three sites can be addressed each year.

X. MILESTONES

Milestones presently include averaging 3 mine site remediations per year and a review of achievements to meeting the goal based stream standards every five years. Although stream standards were adopted in 2001, it is realized they will not be met until all planned remediation is accomplished. Therefore 'temporary modifications' have been set for an interim period of five years. ARSG will analyze new monitoring data and compare the results to those of what is referred to as the 'existing condition' – those stream conditions established in the 2001 UAA. The existing condition is considered, for practical purposes, a pre-remediation condition, even though several remediation projects had already been completed. The analysis will be presented to the WQCC in 2006 and recommendations will be made for new temporary modifications that will reflect remediation accomplishments. Overall completion of the plan is not expected before 20 years due to the large amount of projects that must be accomplished, lack of adequate funding, and lack of liability relief that is necessary for third parties such as the ARSG to address draining mines.

XI. MEASUREMENT OF ACHIEVEMENT

Evaluation of individual remediation projects, as well as geochemical evaluations at the four gauges and biomonitoring at key locations, will be a component of both the evaluation of remediation and future remediation planning processes. The ARSG will continue to collect data from property owners, public land managers, and other participating entities to evaluate the effectiveness or remediation techniques and to communicate those successes and failures to the public.

The primary criteria to be used for evaluation will be meeting the newly adopted stream standards, which include specific aquatic life. Information will be collected, analyzed, and presented periodically to the WQCC. Temporary modifications to the stream standards, set by the Commission, will reflect what has been accomplished and what remains to be done.

REFERENCES:

Simon, W., Butler, P., Owen, R., 2001. Use Attainability Analysis for the Animas River Watershed. Animas River Stakeholders Group (presented to Colorado Water Quality Control Commission for the adoption of steam standards). 240p., several appendices, CD ROM w/data.

Herron, Jim, Bruce Stover, Paul Krabacher, and Dave Bucknam, *Mineral Creek Feasibility Investigations Report*, Colo. Division of Minerals and Geology, Feb. 1997.

Herron, Jim, Bruce Stover, and Paul Krabacher, *Cement Creek Reclamation Feasibility Report*, Colo. Division of Minerals and Geology, Sept. 1998.

Herron, Jim, Bruce Stover, and Paul Krabacher, R*eclamation Feasibility Report Animas River above Eureka*, Colo. Division of Minerals and Geology, Oct. 1999.

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APPENDIX A

ANIMAS USE ATTAINABILITY ANALYSIS
TABLE OF CONTENTS

Contents of the UAA are bound in several folders. Water quality data and some worksheets are provided only on CD-ROM #1. In addition, the entire UAA is available on CD-ROM #2.

I. UAA TEXT AS SEPERATELY BOUND FOLDERS

<u>INCLUDES THE FOLLOWING:</u>

CHAPTER XII - RECOMMENDATIONS

II. UAA APPENDICES AS SEPARATELY BOUND FOLDERS

<u>APPENDICES 6A, 6B, 6C</u>
Appendix 6A - Fisheries Report
Appendix 6B - Macroinvertebrate Report
Appendix 6C - Toxicity Report

<u>APPENDICES 7A, 7B, 7C</u>
Appendix 7A - Geology
Appendix 7B - History
Appendix 7C - Mining History

<u>APPENDIX 10A</u> - Mineral Creek Remediation Feasibility

<u>APPENDIX 10B</u> - Cement Creek Remediation Feasibility

<u>APPENDIX 10C</u> - Upper Animas Remediation Feasibility (Above Eureka)

<u>APPENDIX 10D</u> - Upper Animas Remediation Feasibility (Below Eureka)

III. CD-ROM #1

<u>INCLUDES THE FOLLOWING UAA DATA AND WORKSHEETS</u>:
APPENDIX 8A - ARSG Water Quality Data
Mineral Creek
Cement Creek
Upper Animas
Lower Animas

APPENDIX 8B - Analyses of Water Quality Data and Modeled Data

APPENDIX 8C - Description of water quality regression method (WQRM)

APPENDIX 10E - Adit and Mine Waste Rank and Prioritization Tables

APPENDIX 11A
-Combined Adit Load and Cost Calculations
-Combined Mine Waste Load and Cost Calculations

IV. CD-ROM #2

INCLUDES ALL COMPONENTS OF THE UAA

APPENDIX B

Table 3.1

Summary of Reclamation Projects (Updated 11/17/03)

(1) Project Sponsor	(2) Project Site Name	(3) Location	(4) Type of Remediation	(5) Project Timeframe	(6) Funding (incl. in-kind match)	(7) Improvements (actual or anticipated)
Sunnyside Gold Corp.	Lead Carbonate Millsite	Gladstone on bank of S. Fork of Cement Creek	Removal of 27,000 yards of tailings from streambank	Completed 1991	SGC: $163,000	Reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Mayflower Mill – Tailings Ponds #1, #2 and #3	Mayflower Mill complex near Boulder Creek and Animas River	Re-contour inactive tailings ponds and cap. 625,000 yards of tailings and overburden moved.	Completed 1991-1992	SGC: $1,755,000	Mined land reclamation –reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Lake Emma Sunnyside Basin	Sunnyside Basin headwaters of Eureka Creek	Fill mine subsidence, remove 240,000 yards mine waste and re-contour disturbances.	Completed 1991-1993	SGC: $911,000	Mined land reclamation and reduce loading of metals
Sunnyside Gold Corp.	American Tunnel waste dump	Gladstone on bank of S. Fork of Cement Creek	Remove 90,000 yards of waste dump and underlying historic tailings	Completed 1995	SGC: $766,500	Mined land reclamation and reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Eureka Townsite	On banks and In floodplain of Animas River	Remove 112,000 yards of tailings	Completed 1996	SGC: $843,000	Reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Gladstone	Cement Creek at Gladstone	Divert and treat Cement Creek to mitigate any short term impacts of reclamation projects	8/96-5/99, 11/99-12/99	SGC: $901,000	Reduce loading to Animas River to offset any short term impacts of reclamation of other sites.
Sunnyside Gold Corp.	Boulder Creek Tailings	Flood plain of Boulder Cr. and the Animas River	Remove 5700 yards of tailings	Completed 1997	SGC: $32,500	Reduce loading of metals and erosion transport of tailings
Sunnyside	Ransom adit	Eureka townsite	Bulkhead seal to stop deep	Completed	SGC: $85,400	Restore hydrologic regime and

Gold Corp.		above old mill foundation	mine drainage and reclaim portal	1997		reduce rate of ore oxidation by placing mine workings under water to reduce metal loading.
Sunnyside Gold Corp.	Gold Prince mine waste and tailings	Headwaters of Placer Gulch	Bulkhead seals to stop deep mine drainage. Consolidate mine waste and tailings (moved 6000 yards) and construct upland diversions	Completed 1996-1997	SGC: $151,000	Reduce exposure to water to reduce metal loading
Sunnyside Gold Corp.	Longfellow-Koehler	Headwaters of Mineral Creek near top of Red Mountain Pass	Remove Koehler dump (32,100 yards), consolidate Junction Tunnel dump and Longfellow dump and cap. Capture adit drainages.Construct diversions. Feasibility study of wetland treatment of Koehler drainage.	Completed 1996-1997	SGC: $580,000	Reduce metal loading and erosion transport of mine waste
Sunnyside Gold Corp.	Pride of the West tailings	Howardsville near confluence of Cunningham Creek with Animas River	Remove 84,000 yards of tailings	Completed 1997	SGC: $490,500 TUSCO: $14,000	Reduce metal loading and transport of tailings by erosion
Sunnyside Gold Corp.	Sunnyside Mine	Sunnyside Mine Lake Emma Area	Inject 652 tons of hydrated lime into the Sunnyside Mine pool to provide increased alkalinity and improve initial mine pool conditions	Completed 1996-1997	SGC: $313,000	Improve initial conditions as water table is restored through bulkheading to stop mine drainage
Sunnyside Gold Corp.	Mayflower Upland Hydrological Control	Mayflower Mill and Tailings Pond #1 area near Silverton	Capture and divert three upland drainages that were going sub-surface up-gradient of the mill and TP #1 facilities	Completed 1998-1999	SGC: $186,000	Minimize potential for contact of runoff with tailings and reduce potential for metal loading
Sunnyside Gold Corp.	TP #4 drainage modification	Drainage ditch between Hwy. 110 and TP #4 near Silverton	Install lined diversion ditch to capture surface runoff and prevent infiltration through tailings material	Completed 1999	SGC: $72,000	Minimize potential for contact of runoff with tailings and reduce potential for metal loading

		and Animas R.				
Sunnyside Gold Corp.	TP #4 upland groundwater diversion	Up-gradient from Tailings Pond #4 near Silverton	Capture groundwater and divert around tailings impoundment	Completed 1993-1995, 1999	SGC: $409,000	Minimize potential for contact of groundwater with tailings and reduce potential for metal loading
Sunnyside Gold Corp.	Sunnyside Mine hydraulic seal project	Sunnyside Mine	Bulkhead placement in Sunny-side Mine to restore hydrologic regime to approximate pre-mining and eliminate drainage from adits (6 bulkheads)	Completed 1992-1996	SGC: $2,346,000	Place mine workings under water to reduce oxidation, restore groundwater movement around mine workings and eliminate need for perpetual water treatment
Sunnyside Gold Corp.	Power Plant Flats	Power Plant Flats, Animas River floodplain	Removal of mill tailings from floodplain	Completed 2003	SGC: $?	Excavate buried tailings and dispose into Mayflower Tailings Pond #4
Sunnyside Gold Corp.	Mogul Mine Bulkhead	Mogul Mine, Upper Cement Crk.	Stop discharge of AMD from Mogul Mine	Summer, 2003	SGC: $?	Reduce metal loading to Upper Cement Crk
Sunnyside Gold Corp.	Kohler Mine Bulkhead	Kohler Mine, Headwaters of Mineral Crk	Stop discharge of AMD from Kohler mine	Summer, 2003	SGC: $?	Reduce metal loading to Mineral Crk. Headwaters
Sunnyside Gold Corp.	Reactive Wall	Animas floodplain below MF. Tailings #4	Treat contaminated groundwater before entering Animas River	Fall, 2003	SGC: $?	Reduce metal loading to Animas River
Gold King Mines Corp	Gold King Mine	Gladstone, N. Fork of Cement Creek	Hydrologic controls for workings and mine waste	1998	Gold King: $117,300	Reduce metal loading to North Fork of Cement Creek
Gold King Mines Corp	Gold King Mine discharge	Gold King discharge treatment	Pipe mine discharge to Gladstone to actively treat	2002	Gold King: $?	Reduce metal loading to Upper Cement Crk.
Silver Wing Mining Co	Silver Wing	Animas river, about 1.5 mile above Eureka	Collect AMD, hydrological controls	1995	Silver Wing $7,000	Remove AMD from dump, reduce metals loading
Silver Wing Mining Co	Silver Wing	Animas River, about 1.5 miles above Eureka	Anoxic Drain, settling pond, bioreactor	1999-2000	**NPS 319 Funds**: $216,000. St.	Reduce metal loading to the Animas River.

					Severance tax: $144,000	
San Juan RC & D (ARSG)	Carbon Lakes Mine Dump	Headwaters of Mineral Creek East of Red Mountain Pass	Removal of 1,900 cubic yards of waste rock from stream channel	Phase 1 – completed 1999	**NPS 319 Funds**: $72,000 ARSG match: $62,800	Reduce loading of metals especially Cadmium, Copper, Iron, Lead, Manganese, and Zinc
San Juan RC & D (ARSG)	Carbon Lakes Mine Waste Phase II Part 1	Headwaters of Mineral Creek East of Red Mountain Pass	Complete removal of waste rock from stream channel	2001 season	**NPS 319 Funds**: $38,000 ARSG Match: $51.000	Reduce loading of metals to Animas River, restore stream channel, revegetate
San Juan RC & D (ARSG)	Carbon Lakes Phase II, Part 1	Headwaters of Mineral Creek East of Red Mountain Pass	Removal and disposal of 3000 tons of Congress Mine Dump wastes	2001 season	**NPS 319 Funds**: $38,500 ARSG Match: $42.500	Reduce loading of metals to Animas River by beginning the removal of mine wastes.
San Juan RC & D (ARSG)	Carbon Lakes Phase II, Part 2	SanAntonio &Kohler Tunnel infiltration control	Infiltration Control: Purchased Carbon Lakes Trans-basin diversion rights; abandoned ditch	2001 season	**NPS 319 Funds**: $50,000 ARSG Match: $33.333	Reduce water infiltration to the San Antonio and Koehler Mines; reduce AMD
San Juan RC & D (ARSG)	Carbon Lakes Phase III	Congress Mine, Mineral Crk. headwaters	Complete removal of Congress mine wastes	2003	**NPS 319:** $174,000**;** July, 2003; St. Min. Severance Tax: $?	Reduce metal loading to Animas River by removal of mine wastes and benefaction.
San Juan RC & D (ARSG)	Carbon Lakes Phase III	Carbon Lakes Ditch	Ditch, Wetland and Stream Restoration	2003	**SWWCD: $5,000; USFS: $12,400**	Return Mineral Crk headwaters to natural hydrology; erosion controls; restoration of transbasin diversion ditch; wetland restoration.
Mining Remedial Recovery	Sunbank Group	Placer Gulch	Anoxic drain, settling pond, waste consolidation, bulkhead	1995	NPS 319 Funds: $58,000 MRRC: 38,500	Raise pH from draining adit, reduce metal loading from adits and mine waste
Salem Minerals	Mammoth Tunnel	North Fork of Cement Creek	Settling ponds for mine drainage	1999	NPS 319 Funds: $10,050. St. Severance tax:	Focused on reductions of iron to Cement Creek

					$6,700	
Office of Surface Mining	Galena Queen	Prospect Gulch	Waste consolidation & hydrological controls	1998	Office of Surface Mining: $10,000	Reduce surface water leaching of toxic metals
San Juan RC&D (ARSG)	Galena Queen and Hercules	Prospect Gulch	Waste Removal, hydrol. controls, amendments, revegetation.	2001	**NPS 319 Funds**: $94,800 Mineral Sev: $90,000	Elimination of surface water leaching of toxic metals. Post remediation monitoring begins in 2002.
U.S. BLM	Joe & John Tunnel	Prospect Gulch	Mine drainage collection and diversion	1998-1999	BLM: $36,000	Collect AMD for later treatment project development
U.S. BLM	Lark Mine	Prospect Gulch	AMD collection, hydrological controls	1999	BLM: $17,800	Collect AMD for possible treatment, remove surface water from site
U.S. BLM	Forest Queen	Animas near Eureka	AMD collection and passive wetland treatment	1998-1999	BLM: $290,000	Reduce metal loading to Animas River
U.S. BLM	Mayday Mine	Cement Creek	Hydrological controls, cap top of mine waste pile	1998-1999	BLM: $87,000	Reduce surface water leaching of toxic metals
U.S. BLM	Lackawanna Tailings	Animas near Silverton	Removal of tailings from flood plain to Mayday dump for consolidation and capping.	2000	BLM: $300,000	Reduce metal loading to Animas River
U.S.BLM	Elk Tunnel	Cement Crk	Passive treatment of mine discharge	2003	BLM: $110,000	Reduce Fe loading to Cement Crk
U.S. F.S.	Bonner Mine	North Fork of Mineral Creek	Waste removal and consolidation; capture mine drainage and roroute	2000	F. S.: $63,384	Reduce metal loading ot N. Fork Mineral Creek from mine waste and draining adit

Total For Each Entity (through 2002 only)

PRIMARY SPONSOR	TYPE OF PROJECT	Primary Fund Source/Amt.	Match Source and Amount	Total Construction Cost
SJRC&D (ARSG)	NPS 319 – Mine wastes	NPS 319 / $329,635	SGC, St. Severance Tax/ $219,757	$549,392
SJRC&E (ARSG)	NPS 319 – Mine Wastes	NPS 319/ $362,740	St. Severance Tax;, Silver Wing Co. / $472,500	$835,240
Forest Service	AML Mine Wastes & mine drainage control	U. S. Forest Service / $63,384	none	$63,384
BLM	Mine Wastes	BLM / $440,800	None	$440,800
BLM	Mine drainage treatment	BLM / $290,000	None	$290,000
Office of Surface Mining	Mine Waste treatment	OSM / $10,000	none	$10,000
Other Private Companies	Mine drainage treatment	Owners / $124,301	None	$124,301
Other Private Companies	Mine Waste treatment	NPS / $58,000	$38,500	$96,500
Other Private Companies	Mine Waste treatment	NPS / $226,050	$150,700	$376,750
TOTAL FROM ALL ENTITIES (except SGC)	Mine waste and drainage treatments combined	**$1,904,910**	**$881,457**	**$2,786,367**
Sunnyside Gold Corp (SGC)	Mine Waste Treatments	$10,219,600	none	$10,219,000
TOTAL WITH ALL ENTITIES	**Mine waste and drainage treatments combined**	**$12, 124, 510**	**$881,457**	**$13,005,367**

Blue type = projects to be implemented in 2003.

APPENDIX 11 OF THE UAA

This appendix consists of two large spreadsheets only available on the Animas UAA CDROM.